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SPRINGFIELD COLLEGE STUDIES IN PHYSICAL EDUCATION

Supplement to the Research Quarterly, May, 1935, Volume VI, No. 2

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The Reliability and Objectivity of Blood-Pressure Measurements

By J. H. McCurdy, A.M., M.D., M.P.E.,
and
L. A. Larson, B.A., B.P.E., M.Ed.

INTRODUCTION

THE purpose of this study was threefold: (1) To ascertain the accuracy of blood-pressure measurements by arranging the "experimental conditions" in such a manner that errors in readings would be due to the inaccuracy of the measurement rather than to improper "experimental conditions." (2) To validate a research now being conducted by the authors in which blood pressures are found to be important in determining organic efficiency. (3) To find out whether blood-pressure tests can be taken with sufficient accuracy to serve as an index of physical "condition."

A similar study has been made by Schwartz, Britton, and Thompson of the United States Public Health Service in which they found the following in regard to the reliability of blood-pressure measurements:[1]

(1) Systolic Pressure	.65
(2) Diastolic Pressure	.46
(3) Pulse Pressure	.46
(4) Difference between standing and lying systolic pressure	.41

The low coefficients of reliability in this study are due to the "experimental conditions," which were improper for a study of reliability and not to the inaccuracy of the measurement as one would think. Measurements taken to determine the degree of reliability should be taken as soon after each other as possible so as to eliminate "experimental" errors resulting from changes in the function being measured. This is especially true for blood pressures as slight changes occur provided careful measures are not taken to avoid these changes. If the blood-pressure measurement is taken during the time in which there has been a slight change in the pressure, a low coefficient of reliability will be obtained for the measurement, which would generally be interpreted as inaccuracy of the measurement, but should be interpreted as "improper" experimental conditions. The "true" reliability for the measurements can only be obtained when the "experimental conditions" are so

[1] Schwartz, Britton, and Thompson, *The Effect of Exercise on the Physical Condition and Development of Adolescent Boys*, p. 10. Washington: Bulletin No. 179, 1928, United States Public Health Service.

arranged that there will be no fluctuation in the pressures. Schwartz and his associates took the first blood-pressure measurement in February, and the second measurement four months later, in June. Apparently, no attempt was made to eliminate experimental errors so as to obtain the "true" reliability coefficients. To clarify as to what is meant by "experimental" errors due to the "improper" conditions, therefore a fluctuation in the pressures, the following reasons are given: (1) Seasonal changes in blood pressure,[2] i. e., this is an important consideration when measurements are taken at different seasons of the year to determine the reliability of the measurement. (2) Position of the subject during examination, especially in a study of reliability where it is essential to have the same position for all measurements.[3] (3) Temperature of the examining room during measurement.[4] This is an important consideration where the second measurement is taken some days, weeks, or months after the first measurement. (4) Growth and age[5] — in studies where adolescent boys are used the effect of growth and age on blood pressure is an essential consideration. (5) Diurnal variations.[6] This, of course, must be taken into consideration in blood-pressure measurements where the accuracy of the measurement is desired. (6) Instrumental errors.[7] Without first determining the accuracy of the instruments, measurements for the reliability of the object or function are worthless.

ELIMINATION OF EXPERIMENTAL ERRORS

The "experimental conditions" were arranged in this research so as to eliminate as nearly as possible the experimental errors. Therefore the coefficients of reliability and objectivity obtained in the study indicate the "true" accuracy and "consistency" of the blood-pressure measurements. The instruments used were examined thoroughly so as to eliminate the instrumental source of error; therefore, we can say that there were no errors arising from faulty adjustment of instruments. Another source of "experimental" error according to Goodwin[8] are the "personal errors." These errors arise from characteristic peculiarities of individual observers. In blood-pressure measurements this is an essential consideration as the technique of various examiners differs. Any error in technique would certainly lower the coefficients of reliability and objectivity. This error was eliminated by securing experienced examiners of blood pressure. Goodwin[9] suggests another source of experimental error which is applicable in this study, this being errors arising from imperfections or fatigue of the eye and ear of the examiner. The error resulting from fatigue was eliminated by examining

2-6 inc. J. H. McCurdy, *Physiology of Exercise.* Philadelphia: Lea & Febiger, 1928. 2. p. 81; 3. p. 76; 4. p. 83; 5. p. 77; 6. p. 80.

7 H. M. Goodwin, *Elements of the Precision of Measurements and Graphical Methods,* p. 8. New York: McGraw-Hill Book Co., 1920.

8-9 H. M. Goodwin, *Ibid.,* 1. p. 9; 2. p. 11.

only 30 men per full day and the examination of the 164 men covered 6 days. Errors due to ear imperfections were not considered; however, it can be safely assumed that this was not a source of experimental error. Four examiners were used all having a great deal of experience in blood-pressure work and, apparently, no sign of ear defects.

One of the most common sources of experimental error, especially in blood-pressure measurements for accuracy and consistency, will be found in the "methods" or set-up for examination. These errors were minimized by arranging the "experimental conditions" as follows: (1) The subject was placed in a horizontal position and was not allowed to move or talk until all three examiners had finished their examinations. (2) The subject was given not less than five minutes rest before the first measurement was taken, also an interval of rest between the second and third measurements. (3) The same blood-pressure instruments were used on each subject by all examiners. (4) Each examiner obtained enough measurements so as to be certain of the measurement before indicating the reading to the recorder. (5) The blood-pressure readings were written on a slip of paper by each examiner and given to the recorder so the following examiner did not have an opportunity to see the previous reading made. (6) The room was kept as quiet as possible so the readings could be made accurately.

RELIABILITY

In order that the results of any measurement, whether direct or indirect, may be of any scientific or technical value, it is necessary to have some numerical estimate or measure of its reliability.[10] The coefficient of reliability represents the correlation between two sets of measurements of blood pressure which have been made by the same examiner, using the same instruments, and under precisely the same "experimental conditions."

A measure is said to be reliable if two or more measurements of the same object or function by the same measuring device yield the same scores.[11] To this definition the authors want to add—provided that all known sources of error in instruments or methods have been eliminated or corrected for. The latter part of the definition was given careful consideration by the authors so as to be able to determine through the use of the coefficient of reliability the "true" accuracy of the blood-pressure measurements. If the instruments used were perfectly reliable, the experimental conditions for each series of measurements identical, and the blood-pressure measurements in each series the same, the coefficient of reliability would be perfect, or 1.00. Of course, this is impossible, as perfectly accurate measurement of blood

[10] H. M. Goodwin, *Ibid.*, p. 7.

[11] F. R. Rogers, *Fundamental Administrative Measures in Physical Education*, p. 19. Newton, Mass.: The Pleiades Co. 1932.

pressure, i.e., to within 1 or 2 m.m., cannot be made under ordinary conditions unless by chance. However, we have shown through our results that blood-pressure measurements can be made accurately enough to be of real scientific value, also that tests which contain blood pressures will be valid as far as accuracy of the measurement is concerned.

The statistical methods used will be explained in another section of this report and only enough explanation will be given in this section to be able to interpret the meaning of the numerical values in the following tables. These explanations will be found as a footnote. This table contains the coefficient of reliability with the probable error, the index of reliability, the average deviation of a single observation in m.m.Hg., and the deviation of the mean (A.D.).

METHODS OF EXPRESSING ACCURACY THROUGH CORRELATIONS AND DEGREE OF ERROR

	Coefficient of Reliability and Probable Error (1)	Index of Reliability (2)	Av. Deviation of a single observation *A.D.* (3)	Deviation of the mean *A.D.* (4)
1. Systolic Pressure				
rMcCurdy	.853 ± .047	.923	2.24 mm	.45 mm
rLarson	.952 ± .014	.975	2.56 mm	.44 mm
2. Diastolic Pressure				
rMcCurdy	.813 ± .057	.901	2.48 mm	.50 mm
rLarson	.718 ± .073	.847	2.97 mm	.51 mm
3. Pulse Pressure				
rMcCurdy	.905 ± .031	.951	2.64 mm	.53 mm
rLarson	.932 ± .019	.965	3.50 mm	.60 mm

(1) See page 8 in this report for explanation as to method.

(2) According to Odell[a] the index of reliability is a more important measure of the situation than the coefficient of reliability. The reason is that it indicates the errors in only one series of measures, while the coefficient of reliability indicates two sets of errors, one in each series to be correlated. According to Odell it measures the relationship between "obtained" scores and "true" scores (this would be the average of a great number of measurements on each subject for blood pressure) and thus the errors in the "obtained" scores. The index is considered valuable in this study as it gives us a criterion.

(3) According to Goodwin[b] the average deviation of a single observation can be obtained by securing the arithmetical mean, or the sum of the deviations from all of the observations divided by the number. The representative symbol is *a.d.*, and it is found in m.m. of Hg. in this study.

(4) According to Goodwin[b] "the mean has a higher degree of probability than any single observation from which it is computed; therefore, it is the reliability of the mean that is important, more so than that of a single observation." The formula is $A.D. = \frac{a.d.}{\sqrt{N}}$.

[a] C. W. Odell, *Educational Statistics*, p. 188. New York: Century Co., 1925.

[b] H. M. Goodwin, *op cit.*, pp. 16-17.

OBJECTIVITY

A measure has complete objectivity if by using two or more examiners on the same subject, with "proper experimental conditions," i.e., elimination of all sources of experimental error, the same scores are obtained. The correlation coefficients of objectivity indicate the "consistency" between examiners, but do not indicate the "accuracy" of the measurement. The reason is as follows: Suppose we use as an example measurements made of the systolic pressure by Karpovich and McCurdy on the same subjects, using the same blood-pressure instruments, and under the same experimental conditions.[12] Each series of measurements made by these two examiners contains errors; therefore, we have no criterion for the accuracy of the measurement.

The authors were anxious to obtain a criterion for these blood-pressure measurements so as to indicate the "accuracy" of the measurements in a more direct manner. According to Odell[13] the "true" score or measurement is the mean of an infinite number of obtained scores which have been corrected for any practice effect or constant error. Odell[13] also says that this value cannot actually be obtained, but from a practical standpoint we may think of it as the mean of as many obtained scores as are available. It was first thought that by taking the average of the three measurements made by the three examiners on the same subject and correlating this average with the measurement made by each examiner we would have the accuracy of the measurement as secured by each examiner. This average, of course, would have to be considered the "true" measurement under these conditions. This would involve a great deal of unnecessary time and labor as the same thought is brought out by the use of a formula, or the index of reliability. This index, then, will be more valuable than the coefficient of objectivity in indicating the accuracy of the measurement. The objectivity coefficients will indicate "consistency" between the examiners.

The coefficients of objectivity were obtained by correlating measurements taken by one examiner with measurements taken by another examiner on the same subjects, using the same instruments and under the same experimental conditions.

The following table will contain the coefficients of objectivity with the probable errors, and the index of reliability.

Key to the Correlations

r_{KM} meaning the correlation between measurements made by Karpovich and McCurdy.

r_{KS} meaning the correlation between measurements made by Karpovich and Sargeant.

r_{MS} meaning the correlation between measurements made by McCurdy and Sargeant.

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[12] See page 4 and 5.

[13] C. W. Odell, *op. cit.*, p. 188.

Number—164 Position—Horizontal	*Coefficients of Objectivity and Probable Errors**	*Index of Reliability*†
1. Systolic Pressure		
r_{KM}	.893 ± .010	.945
r_{KS}	.905 ± .009	.951
r_{MS}	.910 ± .009	.953
2. Diastolic Pressure—Fourth Phase		
r_{KM}	.773 ± .019	.879
r_{KS}	.788 ± .021	.887
r_{MS}	.776 ± .021	.880
3. Diastolic Pressure—Fifth Phase		
r_{KM}	.788 ± .021	.887
r_{KS}	.795 ± .019	.891
r_{MS}	.774 ± .021	.879
4. Pulse Pressure—Fourth Phase Diastolic		
r_{KM}	.860 ± .013	.927
r_{KS}	.864 ± .013	.929
r_{MS}	.871 ± .012	.933
5. Pulse Pressure—Fifth Phase Diastolic		
r_{KM}	.859 ± .013	.926
r_{KS}	.852 ± .014	.923
r_{MS}	.860 ± .013	.927

* See page 8 for explanation as to method.

† The coefficients of objectivity indicates "consistency" between examiners. Errors are found in both series of blood-pressure measurements correlated; therefore, the resulting coefficient will be lowered by the presence of these two sets of errors. The index of reliability is used to indicate the "maximum" value which the objectivity coefficient can take, that is, the "accuracy" of the blood-pressure measurements is obtained by this index.

STATISTICAL METHOD

The coefficient of objectivity expresses the correlation between measures in blood pressure obtained by two applications of the same measuring instrument by two examiners, under the same experimental conditions. The coefficients of objectivity were obtained by the use of the product-moment method of correlation,[14] with measures on one hundred and sixty-four subjects obtained by each of three examiners correlated. The series of measurements correlated are: Karpovich with McCurdy, Karpovich with Sargeant, and McCurdy with Sargeant.

The data for the study of the reliability of the measurements were secured by taking twenty-five measurements on five subjects by McCurdy, and forty measurements on eight subjects by Larson. Of course, these measurements were made in a staggered manner so that the examiners could not recall the previous reading made. The coefficient of reliability was obtained by securing the reliability coefficient for one-half of the test or measure, then using Spearman's formula[15] to find the reliability for the whole test. The procedure was as follows: Two independent sets of measures were obtained by combining measure one with two, three with four, and five with the average of all measures

14–15 H. E. Garrett, *Statistics in Psychology and Education*, pp. 164 and 271. 1931.

on each subject. McCurdy examined five subjects which would give fifteen measurements to be correlated; while Larson examined eight men which gave twenty-four measurements to be correlated. The product-moment method with the deviation from the average[16] was used for these correlations. The coefficient of reliability obtained in each blood-pressure item was introduced into Spearman's formula so as to secure the reliability coefficient for the whole test. By using this formula it is assumed that one-half of the test as we have selected would have the same degree of error in the measurements as the other half of the test.

The formula is as follows: $r = \frac{2r_h}{1 + r_h}$

In this formula r_h is the reliability coefficient for one-half of the test.

The index of reliability was calculated for both the coefficients of reliability and objectivity. The reason was to have some numerical estimate as to the "accuracy" of the measurement. This index represents the correlation between obtained measurements with the "true" measurement as represented by the average of a great number of measurements on the same subject. The value is obtained by merely taking the square root of the reliability or objectivity coefficient.

CONCLUSIONS

1. All blood-pressure measurements show a high degree of consistency as indicated by the objectivity coefficients.

2. All blood-pressure measurements are sufficiently accurate to be of value in scientific studies.

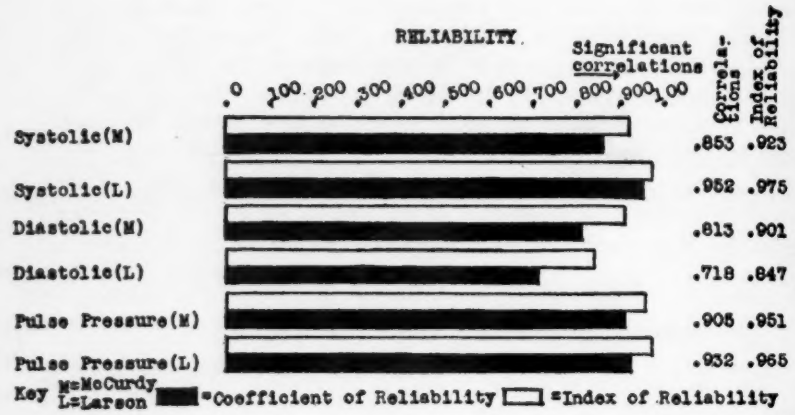
3. The fourth and fifth phase diastolic pressures have both the same degree of accuracy in their measurement.

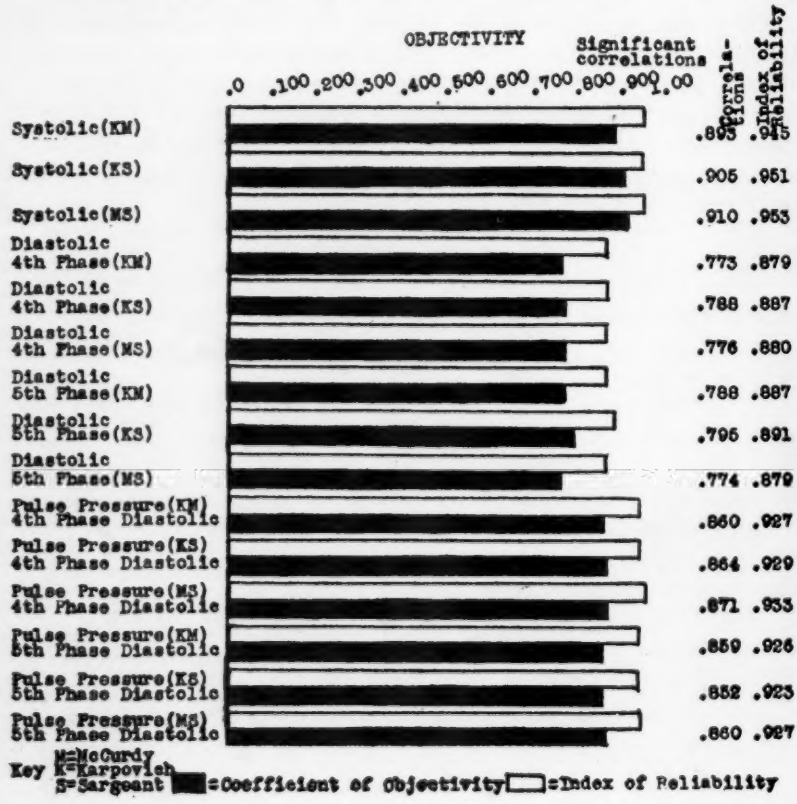
4. The pulse pressure, whether obtained from fourth or fifth phase diastolics, are both as accurately obtained.

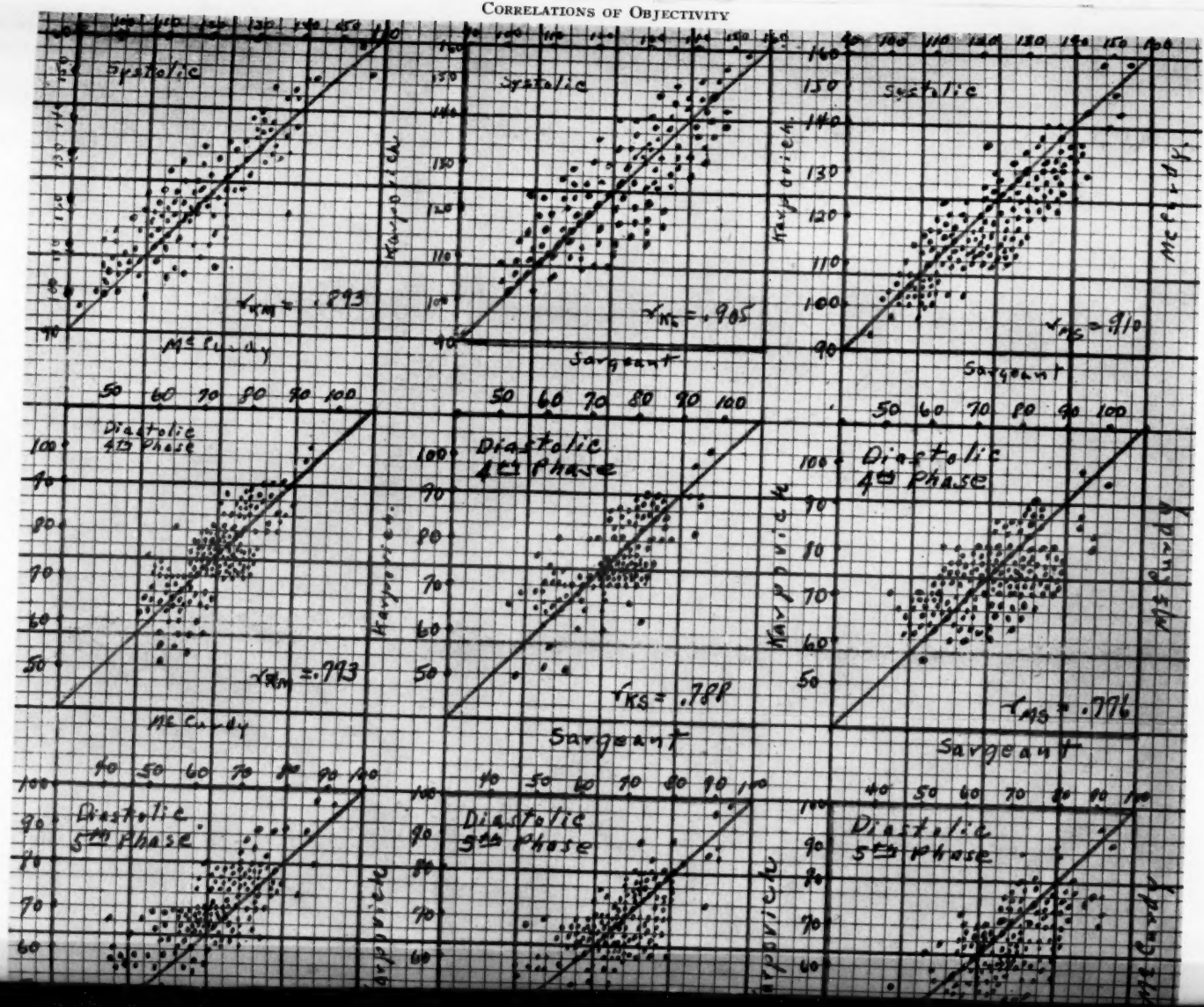
5. In order that a measurement of blood pressure be obtained accurately, all experimental errors must be eliminated in method of examination and in instruments.

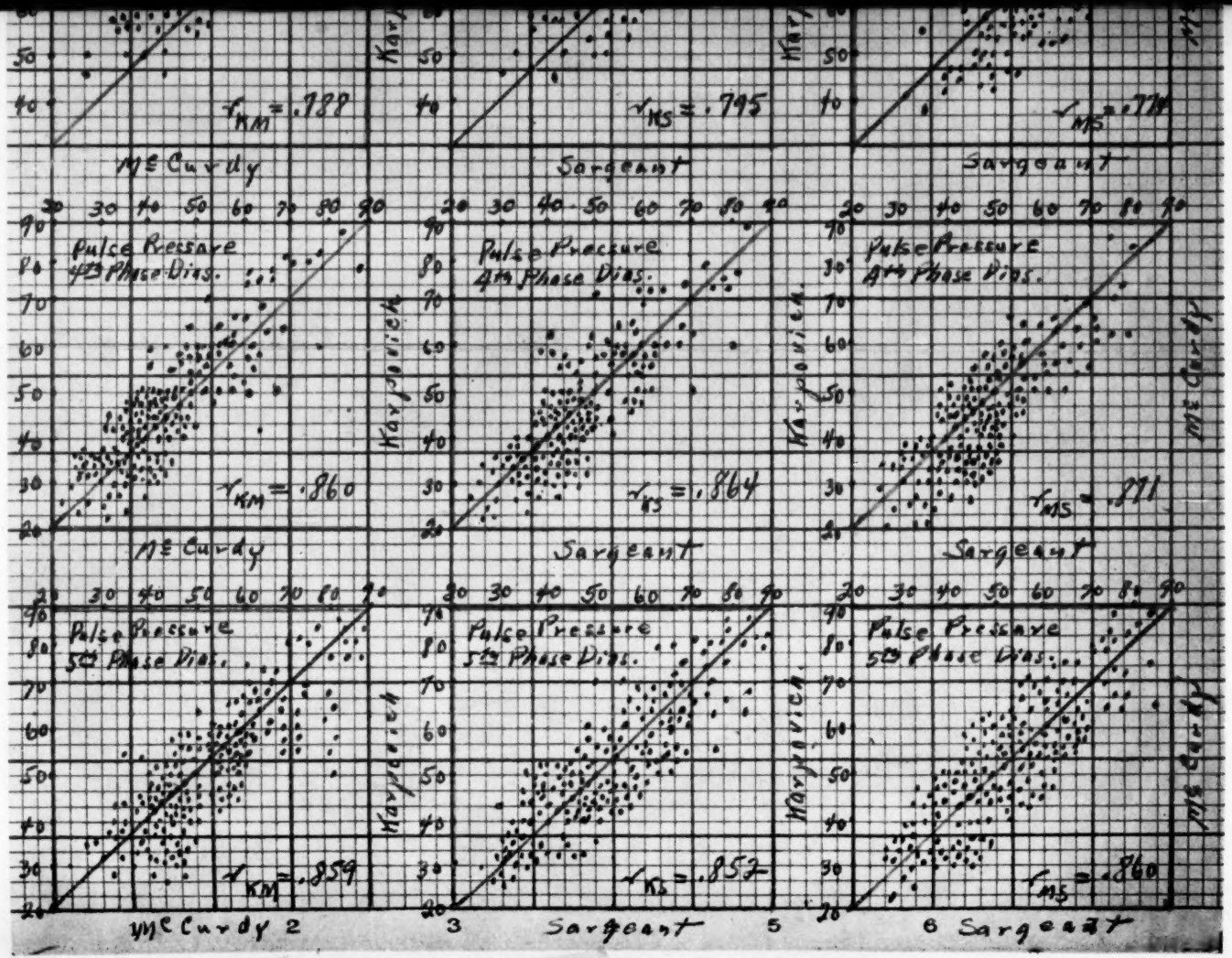
The authors want to express their appreciation to Dr. P. V. Karpovich and Mr. Bliss P. Sargeant, Jr., for their suggestions; also, for their help in conducting the examinations.

[16] K. J. Holzinger, *Statistical Methods for Students in Education*, p. 147. 1928.


RELIABILITY
Significant correlations
.0 .100 .200 .300 .400 .500 .600 .700 .800 .900 1.00
Correlations
Index of Reliability
Systolic(M) .853 .923
Systolic(L) .952 .975
Diastolic(M) .813 .901
Diastolic(L) .718 .847
Pulse Pressure(M) .905 .951
Pulse Pressure(L) .932 .965
Key M=McCurdy L=Larson =Coefficient of Reliability =Index of Reliability


OBJECTIVITY
Significant correlations
.0 .100 .200 .300 .400 .500 .600 .700 .800 .900 1.00
Correlations
Index of Reliability
Systolic(KM) .895 .945
Systolic(KS) .905 .951
Systolic(MS) .910 .953
Diastolic 4th Phase(KM) .773 .879
Diastolic 4th Phase(KS) .788 .887
Diastolic 4th Phase(MS) .776 .880
Diastolic 5th Phase(KM) .788 .887
Diastolic 5th Phase(KS) .795 .891
Diastolic 5th Phase(MS) .774 .879
Pulse Pressure(KM) 4th Phase Diastolic .860 .927
Pulse Pressure(KS) 4th Phase Diastolic .864 .929
Pulse Pressure(MS) 4th Phase Diastolic .871 .933
Pulse Pressure(KM) 5th Phase Diastolic .859 .926
Pulse Pressure(KS) 5th Phase Diastolic .852 .923
Pulse Pressure(MS) 5th Phase Diastolic .860 .927
Key M=McCurdy K=Karpovich S=Sargeant =Coefficient of Objectivity =Index of Reliability


Systolic
Mc Curdy
Hargorieh
Sargeant
Diastolic 4th Phase
Diastolic 5th Phase
$r_{KM} = .793$
$r_{KS} = .905$
$r_{MS} = .910$
$r_{KM} = .793$
$r_{KS} = .788$
$r_{MS} = .776$


r_{KM} = .988
Mc Curdy
Pulse Pressure
3rd Phase Diss.
r_{KM} = .860
Mc Curdy
Pulse Pressure
5th Phase Diss.
r_{KM} = .859
Mc Curdy 2
Marjorie
r_{KS} = .795
Sargeant
Pulse Pressure
4th Phase Diss.
r_{KS} = .864
Sargeant
Pulse Pressure
5th Phase Diss.
r_{KS} = .852
3 Sargeant 5
Marjorie
r_{MS} = .774
Sargeant
Pulse Pressure
4th Phase Diss.
r_{MS} = .891
Sargeant
Pulse Pressure
5th Phase Diss.
r_{MS} = .860
6 Sargeant
Mc Curdy

Measurements of Organic Efficiency for the Prediction of Physical Condition

By J. H. McCurdy, A.M., M.D., M.P.E.,
and
L. A. Larson, B.A., B.P.E., M.Ed.

INTRODUCTION

THESE experiments were begun at the request of Dr. Frederic Brush of the Burke Foundation Hospital. The completion of this study has been made possible through a grant from their funds. Dr. Brush asked us to devise a predictive index of organic efficiency which would aid in the determination of functional fitness to leave their convalescent hospital. The ability to return to ordinary vocations was stressed. Dr. Brush also asked that the predictive index help in measuring the dosage of physical activity needed during the period of recuperation, particularly in golf on the two courses on the hospital estate. Work by McCurdy in the physiology of exercise in the last thirty-five years and an examination by the authors of the literature on organic efficiency raised doubts regarding the statistical reliability of previous work.

Schwartz and his associates in the United States Public Health Bureau challenge the fundamental question of ability to find measures of functional efficiency that are accurate enough to be valid. He says, "Measures of physical fitness (apart from weight itself) .98 are on quite a doubtful basis. Pulse rate led with .71 which seems very low when compared with the results obtained by precise measurements on the body, the blood pressures are much lower." The systolic pressure is .65, the diastolic .46, pulse pressure, .46. The measurements were taken on 68 boys 4 months apart from ages 13 and less to 17 and more (13 and less—4, 14 years—8, 15 years—24, 16 years—20, 17 years and over—12). Schwartz fails to recognize the unreliable method of his test taken on 68 boys 4 months apart. These boys were distributed in age range through the entire adolescent period. His assumption that the comparison of differences in functional measurements taken 4 months apart on growing boys is evidence of reliability is not scientific evidence.

Schwartz's widely quoted apparent proof of inability to measure functional power required a re-examination of the subject with an avoidance of his errors. The first section of this study, "The Reliability and Objectivity of Blood-Pressure Measurements," attempts to find

out whether functional tests can be made with sufficient objectivity and reliability to serve as valid indexes of physical condition.

The second part of the study "Measurements of Organic Efficiency for the Prediction of Physical Condition" selects from a battery of twenty-six items, five test items which have the highest significance as measurements of physical condition. The preliminary examinations cover two years. The examinations included four groups of students in the International Young Men's Christian Association College:

1. College freshmen for the fall seasons of 1933 and 1934—286 men.
2. Infirmary cases from October, 1933, to March, 1935—77 cases.
3. Varsity swimmers for the seasons of 1934 and 1935—49 cases. The time for the 440-yard swim was used as evidence of physical condition. Only experienced swimmers in condition were used in the test. The method aimed to eliminate learning to swim, and to test only physical condition.
4. The case-study group. This group includes men who were in two or all three groups. These case studies permit the comparison of the test on the same individual under different conditions; e.g., in the infirmary and on the varsity swimming team.

The authors are indebted to the 409 students who willingly cooperated as subjects in the long battery of 26 tests. Specific help and cooperation were given by the following faculty members: Dr. Peter V. Karpovich in the blood-pressure examination, Professor T. K. Cureton in the swimming tests, Mr. Bliss P. Sargeant in the heart rates, and Professors Hickox and Cureton on statistical procedures. Dr. Frederick S. Hopkins and Mrs. Pauline Whitney, nurse, gave help in the infirmary studies. The following students assisted as recorders: Messrs. Bicknell, Crowell, Harris, Pawling, and Russell.

The large volume of work entailed in these experiments would have been impossible without the splendid work of all of these groups. All of the statistical work has been done by Mr. L. A. Larson. He also wrote the preliminary draft of the study. The authors collaborated in the final study.

METHOD OF VALIDATION

It is important that norms be established on the basis of healthy groups. We have selected for the criterion of "good" condition 49 varsity swimmers who have been in training for varsity competition; therefore, have learned the fundamental skills. These men have been tested on the basis of their ability to swim 440 yards in varsity time. For the criterion of "poor" condition we have selected 77 infirmary subjects who have been in bed for 2 or more days with fever. For the "average" condition we have used freshmen who have been examined on entrance to the college. This group contains the freshman class for the past 2 years, or 286 in number.

The determination of condition is an extremely complex matter. A person may be able to go about his daily work and yet may not be fit,

or organically efficient for more strenuous work. Many tests have been devised to measure condition. Only a few of these tests have exercise as a measure of organic capacity. Endurance, however, is basic in measuring organic capacity. If one is able to run or swim more than the normal amount without a great amount of fatigue, this can be used as a real criterion of condition. Therefore, in this research we have studied the underlying organic measures of endurance swimming, and have used these items as the criteria. For the other extreme, we have studied infirmary subjects by the use of a number of organic measures.

The authors have used for the test battery twenty-six organic items which have been generally used for examination in the field. By the use of the two extreme groups and correlating these various measures we determined the items that were significant in predicting organic efficiency. We believe a real test or measure of condition can be obtained by using endurance as the criterion of condition, determining the significant organic measures through correlating typical groups, statistically weighting each of these test items, and finally developing a statistically sound scoring device.

DEVELOPMENT OF THE TEST

In beginning the study the author selected the following organic measurements to be used in a test battery: weight; horizontal, sitting, and standing systolic pressures; horizontal, sitting, and standing diastolic pressures; horizontal, sitting, and standing pulse pressures; vital capacity with temperature correction; breath-holding by use of the flarimeter; the standard Prudential stair-climbing exercise; pulse rate immediately after exercise; breath-holding twenty seconds after the exercise; pulse rate sitting one and one-half minutes after exercise; pulse rate standing two minutes after exercise, and the difference between the following items: horizontal and standing pulse rates, horizontal and standing systolic pressures, horizontal and standing diastolic pressures, horizontal and standing pulse pressures, normal breath-holding and breath-holding twenty seconds after the standard stair-climbing exercise, standing normal pulse rate and pulse rate immediately following exercise, sitting normal pulse rate and sitting pulse rate one and one-half minutes following exercise, and standing normal pulse rate and standing pulse rate two minutes following exercise.

These measurements were taken on the swimmers, average group or freshmen, and the infirmary subjects. The first step in determining the important test items for the prediction of condition was to correlate the test items from the infirmary group with the test items of the swimming group. The Bi-Serial "r"[1] for a two-point distribution was used

[1] Richardson and Stalnaker, "A Note on the Use of Bi-Serial *R* in Test Research," *Journal of General Psychology*, VIII: 2 (April, 1933). 463-5.

as the method of correlation. The significant correlations obtained using three groups of data are as follows:

	1933–34 Data	*1934–35 Data*	*Combination or Total*
1. Sitting Diastolic Pressure	—.632	—.574	—.622
2. Breath-Holding Twenty Seconds After Standard Exercise	+.496	+.545	+.531
3. Difference Between Standing Normal Pulse Rate and Pulse Rate Two Minutes after Exercise	+.523	+.439	+.446
4. Sitting Pulse Pressure	+.531	+.400	+.414
5. Standing Pulse Pressure	+.480	+.280	+.346
6. Vital Capacity	+.423	+.277	+.311
7. Standing Diastolic Pressure (Data for two years not separated)			—.350

SELECTION OF TEST ITEMS

It was first thought that the test would contain the following items on the basis of the raw correlations:

1. Sitting Diastolic Pressure	$-.622 \pm .037$
2. Breath-Holding Twenty Seconds after Standard Exercise	$+.531 \pm .043$
3. Difference Between Standing Normal Pulse Rate and Pulse Rate Two Minutes after Exercise	$+.446 \pm .048$
4. Sitting Pulse Pressure	$+.414 \pm .050$
5. Standing Pulse Pressure	$+.346 \pm .053$
6. Vital Capacity	$+.311 \pm .055$
7. Standing Diastolic Pressure	$-.350 \pm .053$

These organic items were used in a multiple correlation development to determine their value as a test battery. The Fisher-Doolittle[2] method of solving a multiple correlation was used. The multiple correlation for the test battery was found to be as follows:

$$R_m = .898$$

It was next decided to eliminate variables (6) and (7) in the test battery to see what effect it would have on the value of the test, or to determine whether or not they were important items in a test. The Fisher-Doolittle method[3] was again used with the resulting multiple correlation:

$$R_m = .881$$

It was next decided to eliminate variable (5) and retain variables (1), (2), (3), and (4) from the test battery. The multiple correlation was found to be as follows:

$$R_m = .826$$

The next step was to eliminate variable (4) and retain variables (1), (2), (3), and (5). The reason for this step was that in solving the multiple correlation with variables (1), (2), (3), (4), and (5) it

[2] By correspondence. Edward E. Cureton, New York City.
[3] *Ibid.*

was found to have the least amount of weight in the test battery. The weighting was so low that it appeared to be unimportant. The result from eliminating variable (4) was as follows:

$$R_m = .806$$

It was decided unnecessary to eliminate variable (1), (2), or (3) from the test battery to see the effect because of their high raw correlations, also because of the large weighting given each of these three variables.

It can be clearly seen on the basis of the multiple correlations that the final test would contain the following items:

	Raw Correlations	*Weighting*
1. Sitting Diastolic Pressure	—.622 ± .037	—6.4
2. Breath-Holding Twenty Seconds after Standard Exercise	+.531 ± .043	+6.6
3. Difference Between Standing Normal Pulse Rate and Pulse Rate Two Minutes After Exercise	+.446 ± .048	+7.7
4. Sitting Pulse Pressure	+.414 ± .050	+1.0
5. Standing Pulse Pressure	+.346 ± .053	+3.0

R_m (organic test) = .881

DESCRIPTION OF THE TEST

It is first necessary in a test to obtain the age and weight of the individual so as to determine the amount of exercise to be given. The exercise (number of ascents on the stairs) is determined by a table prepared by the Prudential Life Insurance Company of America.[4] A copy of this table follows on the next page.

After the amount of exercise to be given in the test is known it is next necessary to secure the standing pulse rate (fifteen seconds and multiply by four), standing systolic and diastolic pressures, and sitting systolic and diastolic pressures. Following these measurements the stair-climbing exercise is given on the basis of the age and weight of the individual. To conduct this test it is necessary to obtain the regulation stairs used for this exercise. The stairs can be obtained at the Becton and Dickinson Company, Rutherford, N. J. Following the exercise, which continues for ninety seconds, the subject is allowed to sit close to a table on which is the flarimeter with the small orifice open. The blow should begin twenty seconds after the exercise with only one large inhalation made before blowing. The subject should be asked to make one large inhalation fifteen seconds following the exercise and blow when ready. This will take approximately five seconds, making the blow twenty seconds following the exercise. The stop-watch used should have two large hands so that one hand will always be continuous. This is necessary in order to obtain the length of the breath-hold-

[4] Medical Department of the Prudential Insurance Company of America, *Determining Circulatory Fitness—Flarimeter Tests*, Table 3, 22. Newark, N.J.

TABLE III

Males

Standard Number of Ascents

(Adapted from Two-step Exercise Test of Master and Oppenheimer)

Wgt. (lbs.)	Age in Years											
	10–14	15–19	20–24	25–29	30–34	35–39	40–44	45–49	50–54	55–59	60–64	65–69
50— 59	28	..	..	..	..	..	..	..	..	..	..	..
60— 69	27	34	..	..	..	..	..	..	..	..	..	..
70— 79	26	32	..	..	..	..	..	..	..	..	..	..
80— 89	26	30	35	36	35	34	32	30	29	27	26	24
90— 99	25	28	33	34	32	31	30	28	27	26	24	23
100—109	24	26	30	31	30	29	28	27	25	24	23	22
110—119	23	25	28	29	28	27	26	25	24	23	22	21
120—129	23	24	27	28	27	26	25	24	23	22	21	20
130—139	22	23	25	27	26	25	24	23	22	21	20	19
140—149	21	23	25	26	25	24	23	22	21	20	19	18
150—159	21	22	24	25	24	23	22	21	20	20	19	18
160—169	20	22	23	24	23	22	21	21	20	19	18	17
170—179	..	22	22	23	22	21	21	20	19	18	18	17
180—189	..	21	21	22	21	21	20	19	19	18	17	17
190—199	..	..	20	21	21	20	20	19	18	17	17	16
200—209	..	..	19	20	20	19	19	18	17	16	16	15
210—219	..	..	18	19	19	18	18	17	16	15	15	14
220—229	..	..	17	18	18	17	17	16	15	14	14	13

ing and also be able to secure the pulse rate accurately two minutes after exercise.

An example will make this clear. Using the face of the watch the exercise will begin at sixty and continue for ninety seconds which will take the hand to thirty. The subject is asked to sit close to the flarimeter and breath normally for fifteen seconds which will take the hand to forty-five on the face of the watch. The subject is asked to take one large inhalation and blow *as long as possible.* The subject should be encouraged to give everything he has in this measurement. When the subject begins the blow the hand on the face of the watch will be on about fifty. The length of the blow will be determined by the organic fitness of the subject. Suppose the blow would stop at twenty and if started at exactly forty-nine seconds, the length of this blow would be thirty-one seconds. The hand on the stop-watch is allowed to continue until it comes to fifteen. The subject is asked to stand. At thirty (two minutes following exercise) the pulse rate is taken for fifteen seconds and multiplied by four. The form used for this test will be as follows:

Name..... Age..... Weight..... Sex.....
Date..... Hour.....

1. Pulse Rate. Standing Normal. 1..... 2.....
2. Blood Pressure
   (*a*) Systolic Pressure (*b*) Diastolic—4th Phase (*c*) Pulse Pressure
   Sitting. 1..... 2..... 1..... 2..... 1..... 2.....
   Standing. 1..... 2..... 1..... 2..... 1..... 2.....
3. Exercise and Measurements following:
   (*a*) Exercise. Number of ascents 1..... 2.....
   (*b*) Breath-holding 20 secs. after exercise 1..... 2.....
   (*c*) Pulse Rate (standing) 2 mins. after exercise 1..... 2.....

NOTE: Two or more spaces should be allowed in the form so that the examination could be repeated at some later date.

In regard to the time required per individual for the organic efficiency test, the maximum is ten minutes. After the examiner has become acquainted with the routine procedure of the test, the time per individual can be reduced two or three minutes.

The equipment necessary to conduct this test is as follows:

1. Stop-watch (Double Action).
*2. Stairs (Prudential Life Insurance Co.).
3. Blood-Pressure Equipment (Sphygmomanometer and Stethoscope).
*4. Flarimeter.

* This equipment may be purchased from the Becton and Dickinson Company, Rutherford, N. J.

ORGANIC MEASUREMENTS IN TYPICAL GROUPS

It was decided to introduce into the study a group of individuals who could be considered "average" from the standpoint of condition; i.e., a group that could not be classified as infirmary subjects, or a group that would not be in excellent condition in terms of endurance swimming. The three groups, also the total number of subjects, will be represented as follows:

A. "Good" condition: Excellent condition for endurance swimming (440 yds.). Number of subjects—49.

B. "Average" condition: Freshmen examined on entrance to College. Number of subjects—286.

C. "Poor" condition: Infirmary subjects who have had fever and in bed for two or more days. Number of subjects—77.

The significant organic items were obtained by correlating the organic test items of Group A ("good" condition) with the organic test items of Group C ("poor" condition). Beginning with twenty-six organic measurements the number dropped to five significant measures by this method. By using these five significant test items, and representing according to the above classification, the following physiological facts are obtained:

1. SITTING DIASTOLIC PRESSURE
   A. "Good" condition—49 subjects—Varsity Swimmers.
   B. "Average" condition—286 subjects—Entering Freshmen.
   C. "Poor" condition—77 subjects—Infirmary Cases.

Correlation Coefficients:

$$r_{AC} = -.622$$
$$r_{BA} = +.208$$
$$r_{BC} = +.541.$$

Physiological Facts:

(1) The "Good" condition group had a lower sitting diastolic pressure than the "Poor" condition group.

Mean for "Good" condition = 78.08.
Mean for "Poor" condition = 89.568.

(2) The "Good" condition group had a higher sitting diastolic pressure than the "Average" group.

Mean for "Good" condition = 78.08.
Mean for "Average" condition = 75.172.

(3) The "Poor" condition group had a higher sitting diastolic pressure than the "Average" group.

Mean for "Poor" condition = 89.568.
Mean for "Average" condition = 75.172.

2. BREATH-HOLDING TWENTY SECONDS AFTER THE STANDARD STAIR-CLIMBING EXERCISE
   A. "Good" condition—49 subjects—Varsity Swimmers.
   B. "Average" condition—164 subjects*—Entering Freshmen.
   C. "Poor" condition—77 subjects—Infirmary Cases.

* The 1933-34 data could not be used as the breath-holding test was taken ten seconds following exercise rather than twenty seconds.

Correlation Coefficients:

$$r_{AC} = +.531$$
$$r_{BA} = +.368$$
$$r_{BC} = -.161.$$

Physiological Facts:

(1) The "Good" condition group had the ability for longer breath-holding after the standard stair-climbing exercise than the "Poor" condition group.

Mean for "Good" condition = 32.832.
Mean for "Poor" condition = 22.864.

(2) The "Good" condition group had the ability for longer breath-holding after the standard stair-climbing exercise than the "Average" group.

Mean for "Good" condition = 32.832.
Mean for "Average" condition = 25.26.

(3) The "Average" condition group had the ability for longer breath-holding after the standard stair-climbing exercise than the "Poor" condition group.

Mean for "Average" condition = 25.26.
Mean for "Poor" condition = 22.864.

3. Difference Between Standing Normal Pulse Rate and Pulse Rate Two Minutes after Standard Stair-Climbing Exercise

A. "Good" condition—49 subjects—Varsity Swimmers.
B. "Average" condition—286 subjects—Entering Freshmen.
C. "Poor" condition—77 subjects—Infirmary Cases.

Correlation Coefficients:

$$r_{AC} = +.446$$
$$r_{BA} = +.248$$
$$r_{BC} = -.017.$$

*Physiological Facts:**

(1) The "Good" condition group had a pulse-rate difference between normal standing and two minutes after exercise of above normal and ranging slightly below normal, while the "Poor" condition group had a pulse-rate difference below normal.

Mean for "Good" condition = +4.532.
Mean for "Poor" condition = −4.024.

(2) Comparing the "Average" group with the "Good" condition group the "Average" group had a pulse-rate difference between the normal standing and two minutes after exercise of greater variability; i.e., the range was from thirty-two below to thirty-two above normal.

Mean for "Good" condition = +4.532.
Mean for "Average" condition = −3.572.

(3) Comparing the "Poor" condition group with the "Average" group we found that the "Average" group had greater variability in the range.

Mean for "Poor" condition = −4.024.
Mean for "Average" condition = −3.572.

4. Sitting Pulse Pressure

A. "Good" condition—49 subjects—Varsity Swimmers.
B. "Average" condition—286 subjects—Entering Freshmen.
C. "Poor" condition—77 subjects—Infirmary Cases.

Correlation Coefficients:

$$r_{AC} = +.414$$
$$r_{BA} = +.063$$
$$r_{BC} = -.256$$

* Plus (+) means above normal; minus (—) means below normal.

Physiological Facts:

(1) The "Good" condition group had a higher sitting pulse pressure than the "Poor" condition group.

Mean for "Good" condition = 44.448.
Mean for "Poor" condition = 35.036.

(2) The "Good" condition group had a higher sitting pulse pressure than the "Average" group.

Mean for "Good" condition = 44.448.
Mean for "Average" condition = 42.396.

(3) The "Poor" condition group had a lower sitting pulse pressure than the "Average" group.

Mean for "Poor" condition = 35.036.
Mean for "Average" condition = 42.396.

5. STANDING PULSE PRESSURE

A. "Good" condition—49 subjects—Varsity Swimmers.
B. "Average" condition—285 subjects—Entering Freshmen.
C. "Poor" condition—77 subjects—Infirmary Cases.

Correlation Coefficients:

rAC = +.346
rBA = +.039
rBC = —.040.

Physiological Facts:

(1) The "Good" condition group had a higher standing pulse pressure than the "Poor" condition group.

Mean for "Good" condition = 37.252.
Mean for "Poor" condition = 29.556.

(2) The "Good" condition group had a slightly higher standing pulse pressure than the "Average" condition group.

Mean for "Good" condition = 37.252.
Mean for "Average" condition = 35.94.

(3) The "Poor" condition group had a lower standing pulse pressure than the "Average" condition group.

Mean for "Poor" condition = 29.556.
Mean for "Average" condition = 35.94.

RELIABILITY OF THE TEST

The reliability will be developed under two parts: first, the reliability and objectivity of the test items, and second, the reliability of the test battery in predicting condition.

There has been a great deal of comment made in the field in regard to the value of a test containing blood pressures because of the inaccuracy of their measurements. However, the authors were unable to find a careful study in regard to the reliability and objectivity of blood-pressure measurements. It was, therefore, decided to conduct a study[5] to determine the consistency by which blood-pressure measurements are made. The results of this study were as follows:[6]

[5] J. H. McCurdy, and L. A. Larson, "The Reliability and Objectivity of Blood-Pressure Measurements," pp. 3-10, this Supplement.

[6] For complete results, see above reference (5).

	Diastolic Pressure 4th Phase	*Pulse Pressure 4th Phase—Diastolic*
1. Reliability		
rMcCurdy	.813	.905
rLarson	.718	.932
2. Objectivity		
rMcCurdy and Karpovich..	.773	.860
rMcCurdy and Sargeant....	.776	.871
rKarpovich and Sargeant..	.788	.864

The organic efficiency test contains the sitting diastolic pressure, the sitting pulse pressure, and the standing pulse pressure. It can be concluded on the basis of the above study that these organic measurements can be obtained accurately enough to render the test valid.

The reliability of the test battery is indicated by the two following values:

$$R_m = .881$$

RCoefficient of reliability for the test $= .845$.

The coefficient of reliability for the test was obtained by the use of the actual test scores from the "Good" and "Poor" condition groups. The Bi-Serial "r"[7] for a two-point distribution was used as the method of correlation. The following table will show the method used to obtain the reliability coefficient for the test, also the placement of the "Poor" and "Good" condition subjects in the scoring table.

SCORING ORGANIC EFFICIENCY

Percentile	*Rating*	*Score*	*"Poor" Condition Infirmary Cases*	*"Good" Condition Varsity Swimmers*
90	Excellent	759—up	..	12
80	Very Good	758—696	..	10
70	Good	695—627	1	20
60	Above average	626—596	2	3
50	Average	595—	2	..
40	Below average	594—557	10	1
30	Fair	556—474	23	..
20	Poor	473—436	17	..
10	Very poor	435—down	22	..
			N = 77	N = 46

RReliability coefficient $= .845$.

METHOD OF SCORING

In order that the organic test could be of real practical use it was necessary to arrange a short, simple, and yet accurate scoring device. It was finally decided to score each individual in the following manner:

1. Change the raw score of the organic test to the T-scale score. Table I.

[7] Richardson and Stalnaker, *op. cit.*, p. 465.

2. Multiply the T-scale score in each of the organic items by the proper weighting. Table I.

3. Add the total score to obtain the final score for each individual. Table II.

4. Determine the condition rating or classification given the individual by use of percentiles. Table II or III.

An example will make the use of the scoring device clear. The following is an infirmary subject, age twenty-one, in bed with a temperature for six days. He was tested when his temperature became normal, which was at the end of the sixth day.*

Name *M. H.* Date *February 21, 1935*

Test Items	*Raw Score*	*T-Score*	*T-Score × Weight*	*Classification*	
1. Sitting Diastolic Pressure	90	64	—410	90 Excellent	759—up
2. Breath-Holding 20 secs. after standard exercise	12	31.5	+208	80 Very Good	758—696
3. Standing Pulse Rate minus Pulse Rate 2 mins. after exercise...	0	54.5	+420	70 Good	695—627
				60 Above avg.	626—596
				50 Average	595
				40 Below avg.	594—557
4. Sitting Pulse Pressure.	30	42	+42	30 Fair	556—474
5. Stand. Pulse Pressure.	28	46.5	+140	20 Poor	473—436
Classification *Very Poor*		Total	400	10 Very Poor	435—down

*This subject was examined again April 22, 1935. His score in this test was 599 which shows an increase of 49.7 per cent in organic efficiency.

TABLE I

T-Score for Organic Efficiency Items

Sitting Diastolic Pressure			Breath-Holding 20 seconds After Exercise			Difference between Stand. P. R. & P. R. 2 minutes after exercise			Sitting Pulse Pressure			Standing Pulse Pressure		
Pressure	T-score	T-score × −6.4	B.-H.	T-score	T-score × +6.6	Pulse Rate Diff.	T-score	T-score × +7.7	Pulse Press.	T-score	T-score × +1.0	Pulse Press.	T-score	T-score × +3.0
100	77	−493	56	75.5	+498	32	77	+593	76	78	+78	72	80	+240
99	76	−486	55	75	+495	31	76	+585	75	77	+77	71	79	+237
98	74	−474	54	74.5	+492	30	75	+578	74	76	+76	70	78	+234
97	72	−461	53	74	+488	29	74	+570	73	75	+75	69	77	+231
96	70	−448	52	73	+482	28	73.5	+566	72	74	+74	68	76	+228
95	69	−442	51	72	+475	27	73	+562	71	73	+73	67	75	+225
94	67	−428	50	71.5	+472	26	72.5	+558	70	72.5	+73	66	74	+222
93	66.5	−426	49	71	+469	25	72	+554	69	72	+72	65	73	+219
92	65.5	−419	48	70.5	+465	24	71	+547	68	71	+71	64	72.5	+218
91	65	−416	47	70	+462	23	70.7	+544	67	70.5	+71	63	72	+216
90	64	−410	46	69.5	+459	22	70.5	+543	66	70	+70	62	71	+213
89	63	−403	45	69	+455	*21	70.3	+541	65	69	+69	61	70.5	+212
88	62	−397	44	68.5	+452	20	70	+539	64	68.5	+69	60	70	+210
87	61	−390	43	68	+449	19	69.7	+537	63	68	+68	59	69.5	+209
86	60	−384	42	67.8	+447	18	69.5	+535	62	67.7	+68	58	69	+207
85	59	−377	41	67.4	+445	17	69	+531	61	67.3	+67	57	68.5	+206

* All varsity swimmers ("Good" group) range between +24 and −16 in the difference between standing normal pulse rate and pulse rate 2 minutes after exercise, while only one went above +20 and one below −8. Both of these individuals had a total good score; the one with +24 had a total score of 953 and the one with −16 had a score of 694.

(*Table continued on page 24*)

TABLE I—(*Continued*)
T-SCORE FOR ORGANIC EFFICIENCY ITEMS

Sitting Diastolic Pressure			Breath-Holding 20 seconds After Exercise			Difference between Stand. P. R. & P. R. 2 minutes after exercise			Sitting Pulse Pressure			Standing Pulse Pressure		
Pressure	T-score	T-score × −6.4	B.-H.	T-score	T-score × +6.6	Pulse Rate Diff.	T-score	T-score × +7.7	Pulse Press.	T-score	T-score × +1.0	Pulse Press.	T-score	T-score × +3.0
84	58.5	−374	40	67	+442	16	68.5	+527	60	67	+67	56	68	+204
83	57	−365	39	66	+436	15	68	+524	59	66.5	+67	55	67	+201
82	56	−358	38	65.5	+432	14	67	+516	58	66	+66	54	66.5	+200
81	55	−352	37	65	+429	13	66.5	+512	57	65.5	+66	53	66	+198
80	54.5	−348	36	64	+422	12	66	+508	56	65	+65	52	65.5	+197
79	53	−339	35	63	+416	11	65	+501	55	64	+64	51	64	+192
78	52	−333	34	62	+409	10	64	+493	54	63	+63	50	63	+189
77	51	−326	33	61	+403	9	63	+485	53	62	+62	49	62.5	+188
76	50.5	−323	32	60.5	+399	8	62.5	+481	52	61	+61	48	62	+186
75	49	−314	31	59	+389	7	61	+470	51	60	+60	47	61	+183
74	48	−307	30	58	+383	6	60	+462	50	59	+59	46	60.5	+182
73	47	−301	29	57	+376	5	59	+454	49	58	+58	45	60	+180
72	46	−294	28	56.5	+373	4	58	+447	48	57.5	+58	44	59.5	+179
71	45	−288	27	55	+363	3	57	+439	47	57	+57	43	59	+177
70	43.5	−278	26	54	+356	2	56	+431	46	56	+56	42	58	+174
69	42	−269	25	53	+350	1	55	+424	45	55.5	+56	41	57.5	+173
68	41	−262	24	52.5	+347	0	54.5	+420	44	55	+55	40	57	+171
67	40	−256	23	51	+337	−1	54	+416	43	54	+54	39	56	+168
66	39	−250	22	49	+323	−2	53	+408	42	53	+53	38	55.5	+167
65	38	−243	21	47.5	+314	−3	52	+400	41	52	+52	37	55	+165

64	37	—237
63	36	—230
62	35	—224
61	34	—218
60	33	—211
59	32	—205
58	31	—198
57	30	—192
56	29	—186
55	28	—179
54	26	—166
53	24	—154
52	23	—147

20	46	+303
19	44	+290
18	42.5	+281
17	41	+271
16	39.5	+261
15	37	+244
14	35	+231
13	33	+218
12	31.5	+208
11	28	+185
10	26	+172
9	24	+158
8	21	+139

—4	51	+393
—5	50	+385
—6	49	+377
—7	48	+370
—8	47	+362
—9	46	+354
—10	45	+347
—11	44	+339
—12	43.5	+335
—13	43	+331
—14	42	+323
—15	41	+316
—16	40	+308
—17	39	+303
—18	38	+293
—19	37	+285
—20	36	+277
—21	35	+270
—22	34	+262
—23	33	+254
—24	32.5	+250
—25	31	+239
—26	30	+231
—27	29	+223
—28	28	+216
—29	27	+208
—30	25	+193
—31	23.5	+181
—32	22	+170

40	51.5	+52
39	50	+50
38	49	+49
37	48	+48
36	47.5	+48
35	47	+47
34	46	+46
33	45	+45
32	44.5	+45
31	43	+43
30	42	+42
29	41	+41
28	40.5	+41
27	39	+39
26	38	+38
25	37	+37
24	35.5	+36
23	34	+34
22	33	+33
21	32	+32
20	31	+31
19	30	+30
18	29	+29
17	28	+28
16	27.5	+28
15	27	+27
14	26	+26
13	25	+25
12	24	+24

36	54.4	+164
35	54	+162
34	53	+159
33	52	+156
32	51	+153
31	50	+150
30	49	+147
29	48	+144
28	46.5	+140
27	45	+135
26	44.5	+134
25	43	+129
24	42.5	+128
23	41	+123
22	40	+120
21	39	+117
20	38	+114
19	36	+108
18	35.5	+107
17	34	+102
16	33	+99
15	32	+96
14	30.5	+91
13	29	+87
12	28	+84
11	27	+81
10	26	+78
9	25	+75
8	24	+72

TABLE II

CLASSIFICATION TEST AND RECORD CARD[8]

Name..... Date.....

Test Items	*Raw Score*	*T-Score*	*T-Score × Weight*	*Classification*	
1. Sitting Diastolic Pressure	..	..	.....	90 Excellent	759—up
2. Breath-Holding 20 secs. after standard exercise	..	..	.....	80 Very Good	758—696
				70 Good	695—627
3. Standing Pulse Rate minus Pulse Rate 2 mins. after exercise...	..	..	.....	60 Above avg.	626—596
				50 Average	595
				40 Below avg.	594—557
4. Sitting Pulse Pressure.	..	..	.....	30 Fair	556—474
5. Stand. Pulse Pressure.	..	..	.....	20 Poor	473—436
Classification.....		Total.....		10 Very Poor	435—down

TABLE III

SCORING ORGANIC EFFICIENCY OF SUBJECTS EXAMINED*

Percentile	*Rating or Classification*	*Score*	*"Poor" Condition Infirmary Cases*	*"Average" Condition Freshmen*	*"Good" Condition Varsity Swimmers*
90	Excellent	759—up	..	16	12
80	Very Good	758—696	..	18	10
70	Good	695—627	1	39	20
60	Above Average	626—596	2	20	3
50	Average	595	2	..	..
40	Below Average	594—557	10	20	1
30	Fair	556—474	23	24	..
20	Poor	473—436	17	16	..
10	Very Poor	435—down	22	9	..
			N = 77	N = 162	N = 46

* The 1933-34 dots could not be used in the final scoring, due to the fact that the breath-holding test was taken ten seconds following exercise rather than twenty seconds.

CASE STUDIES

In this section of the study we have a number of subjects who have been tested in two or more of the typical groups. In one case we have a subject who was tested on entrance to college, later as an infirmary subject, and still later as a member of the swimming team. This subject represents all three groups in terms of condition; i.e., the "average," "poor," and "good" condition. It is interesting to note that his score was 522 on the entrance test, or as a subject in "average" condition, his score was 454 on the infirmary test, while as a member of the swim-

[8] Bovard and Cozens, *Tests and Measurements in Physical Education*, p. 277. Philadelphia: W. B. Saunders Co., 1930.

ming team he had a score of 620. You will notice at the foot of the following table the average score for "poor" condition was found to be 488.8; the average score for "average" condition was found to be 580.0; while the average score for "good" condition was 671.0. This shows a rise in the score with increased organic efficiency.

The case studies with the three groups of condition represented are as follows:

CASE STUDIES—PHYSICAL CONDITION TABLE

Subject	"Poor" condition or Infirmary subjects with fever	"Average" condition. Examined on entrance to college	"Good" condition. In training for Swimming
1. H	454	522	620
2. P	541	...	674
3. C	529	...	780
4. M	454	515	...
5. B	383	750	...
6. C	...	456	693
7. C	378	520	...
8. H	472	361	...
9. A	448	439	...
10. A	437	607	...
11. C	590	470	...
12. B	581	645	...
13. N	374	457	...
14. M	542	616	...
15. B	422	525	...
16. B	492	722	...
17. H	410	700	...
18. R	503	725	...
19. H	560	643	...
20. W	522	412	...
21. H	589	707	...
22. S	597	466	...
23. L	506	627	...
24. K	459	489	...
25. M	...	833	664
26. B	...	689	694
27. H	...	629	657
28. R	...	462	634
29. C	...	456	693
30. C	...	650	633
31. E	...	592	633
32. O	...	715	678
Average score	488.8	580.0	671.0

PHYSIOLOGICAL NORMS*

	"Poor" condition	*"Good" condition*
1. Sitting diastolic pressure[9]	90 and up	52 to 89
2. Breath-holding twenty seconds after standard stair-climbing exercise	22 and down	23 and up
3. Standing normal pulse rate minus pulse rate two minutes after exercise	—4 and down	—4 up to +20
4. Pulse pressure	10 to 29	30 to 60

CONCLUSIONS

1. The study on reliability and objectivity shows that blood-pressure measurements can be accurately made. Tests which contain blood pressures are valid as far as the measurements are concerned.

2. The research on organic efficiency gives a predicted index which separates clearly the ill group in the infirmary from the varsity swimming group in good condition.

3. The correlations have separated from twenty-six items five items which are significant in the measurement of organic efficiency, comparing the infirmary group with the varsity swimmers.

4. Tests on the same individual show an improvement in "condition" as the athlete reaches varsity form. This is indicated by a rise in the total score for the individual.

5. This organic efficiency test requires experimentation on groups at different age levels, and in a wider variety of activities.

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* These norms are set on the basis of people who do not have an organic defect. A careful examination of the raw data shows in a few cases an overlapping in the figures as given above. These exceptions are so few that they have not materially affected the norms.

[9] A. V. Hill, J. C. Gramwell, and A. C. Downing, *Heart*, X, 289-300, 1923; "Clearly it is impossible for an individual with a high diastolic pressure to obtain a considerable output per beat without developing a dangerously high pressure, and throwing an enormous strain on the heart. Conversely, it is obvious that an individual with a low diastolic pressure will be able to reach a high output without difficulty" as quoted by L. F. MacKenzie, M.D., and P. V. Wells, D.Sc., *On the Interpretation of Blood Pressure*. Newark, N. J.: The Prudential Insurance Company of America, 1933.

APPENDIX I

Organic Efficiency Scores*

Content:

(1) Scores for Infirmary Cases—"Poor" Condition.
(2) Scores for Freshman Group—"Average" Condition.
(3) Scores for Varsity Swimmers—"Good" Condition.
(4) Method of Obtaining Reliability Coefficient for "Organic Efficiency Test."

Scoring Organic Efficiency with Weighted T-Scale
Infirmary—"Poor" Condition—Fever Cases

Subject	Sitting Diastolic Pressure			Breath-Holding 20 secs. after exercise			Difference between Standing P.R. & P.R. 2 mins. after exercise			Sitting Pulse Pressure			Standing Pulse Pressure			Total
Infirmary	Pressure	T-Score	T-Score × −6.4	B.H.	T-Score	T-Score × +6.6	Pulse Rate Diff.	T-Score	T-Score × +7.7	Pulse Press.	T-Score	T-Score × +1.0	Pulse Press.	T-Score	T-Score × +3.0	
1	94	67.5	−432	26	54	+356	−12	43.5	+335	24	35.5	+36	34	53	+159	454
2	96	70	−448	17	41.5	+274	−24	32.5	+250	30	42	+42	30	49	+147	265
3	96	70	−448	21	47.5	+313	+ 8	62.5	+481	38	49	+49	36	54.5	+164	559
4	90	63.7	−408	29	57	+376	−16	40	+308	20	31	+31	10	26	+ 78	385
5	80	54.5	−349	21	47.5	+313	−20	36	+277	50	59	+59	24	42.5	+128	428
6	96	70	−448	15	37	+244	− 4	51	+393	30	42	+42	24	42.5	+128	359
7	98	73.5	−470	30	58	+383	− 8	47	+362	10	24	+24	12	28	+ 84	383
8	88	62	−397	25	53	+350	+ 4	58	+447	12	24	+24	10	26	+ 78	502
9	90	63.7	−408	16	39.5	+261	−16	40	+308	30	42	+42	28	46.5	+140	343
10	90	63.7	−408	23	51	+337	0	54.5	+420	42	53	+53	32	51	+153	555
11	90	63.7	−408	21	47.5	+313	+ 8	62.5	+481	28	40.5	+41	20	38	+114	541
12	84	58.5	−374	16	39.5	+261	− 4	51	+393	26	38	+38	16	33	+ 99	417
13	88	62	−397	16	39.5	+261	−16	40	+308	42	53	+53	32	51	+153	378
14	86	60	−384	36	64	+422	− 8	47	+362	12	24	+24	10	26	+ 78	502
15	88	62	−397	18	42.5	+281	− 4	51	+393	30	42	+42	32	51	+153	472
16	96	70	−448	20	46	+304	− 8	47	+362	36	47.5	+48	46	60.5	+182	448

* 1933–34 freshmen (121) could not be used for final scoring or breath-holding. Was taken 10 seconds after exercise rather than 20 seconds after exercise.

APPENDIX I—(*Continued*)

INFIRMARY—"POOR" CONDITION—FEVER CASES

Subject	Sitting Diastolic Pressure			Breath-Holding 20 seconds After Exercise			Difference between Stand. P. R. & P. R. 2 minutes after exercise			Sitting Pulse Pressure			Standing Pulse Pressure			Total
Infirmary	Pressure	T-Score	T-Score × −6.4	B.H.	T-Score	T-Score × +6.6	Pulse Rate Diff.	T-Score	T-Score × +7.7	Pulse Press.	T-Score	T-Score × +1.0	Pulse Press.	T-Score	T-Score × +3.0	
17	96	70	−448	21	47.5	+313	−12	43.5	+335	24	35.5	+36	26	44.5	+134	370
18	88	62	−397	26	54	+356	− 4	51	+393	32	44.5	+45	20	38	+114	511
19	86	60	−384	20	46	+304	−12	43.5	+335	30	42	+42	28	46.5	+140	437
20	84	58.5	−374	25	53	+350	+ 4	58	+447	40	51.5	+52	24	42.5	+128	603
21	70	43.5	−278	18	42.5	+281	− 8	47	+362	52	61	+61	36	54.5	+164	590
22	94	67.5	−432	21	47.5	+313	0	54.5	+420	40	51.5	+52	28	46.5	+140	493
23	90	63.7	−408	23	51	+337	+ 4	58	+447	34	46	+46	34	53	+159	581
24	96	70	−448	17	41	+271	− 8	47	+362	30	42	+42	30	49	+147	374
25	74	48	−307	29	57	+376	−20	36	+277	46	56	+56	28	46.5	+140	542
26	100	77	−493	20	46	+304	+ 4	58	+447	24	35.5	+36	24	42.5	+128	422
27	90	63.7	−408	16	39.5	+261	− 8	47	+362	54	63	+63	40	57	+171	449
28	96	70	−448	27	55	+363	+12	66	+508	24	35.5	+36	16	33	+ 99	558
29	84	58.5	−374	22	49	+323	− 4	51	+393	40	51.5	+52	26	44.5	+134	529
30	90	63.7	−408	35	63	+416	+ 8	62.5	+481	40	51.5	+52	28	46.5	+140	681
31	80	54.5	−349	22	49	+323	−28	28	+216	40	51.5	+52	28	46.5	+140	382
32	88	62	−397	19	44	+290	− 4	51	+393	28	40.5	+41	24	42.5	+128	455
33	88	62	−397	27	55	+363	−12	43.5	+335	42	53	+53	32	51	+153	507
34	80	54.5	−349	30	58	+382	− 8	47	+362	38	49	+49	30	49	+147	591
35	84	58.5	−374	25	53	+350	− 8	47	+362	46	56	+56	34	53	+159	553
36	94	67.5	−432	24	52.5	+347	− 8	47	+362	36	47.5	+48	38	55.5	+167	492
37	70	43.5	−278	18	42.5	+281	− 8	47	+362	58	66	+66	46	60.5	+182	613
38	86	60	−384	21	47.5	+313	−16	40	+308	32	44.5	+45	24	42.5	+128	410
39	96	70	−448	25	53	+350	0	54.5	+420	32	44.5	+45	18	35.5	+107	474
40	94	67.5	−432	21	47.5	+313	0	54.5	+420	38	49	+49	32	51	+153	503
41	92	65.5	−419	26	54	+356	− 4	51	+393	36	47.5	+48	28	46.5	+140	518
42	80	54.5	−349	18	42.5	+281	− 4	51	+393	38	49	+49	48	62	+186	560

42	80	54.5	−349	18	42.5	+281	− 4	51	+393	38	49	+49	48	62	+186	560
43	90	63.7	−408	11	28	+185	− 4	51	+393	20	31	+31	16	33	+ 99	300
44	80	54.5	−349	24	52.5	+347	− 4	51	+393	30	42	+42	26	44.5	+134	567
45	96	70	−448	16	39.5	+261	+12	66	+508	44	55	+55	34	53	+159	535
46	88	62	−397	20	46	+304	−12	43.5	+335	32	44.5	+45	42	58	+174	461
47	90	63.7	−408	21	47.5	+313	0	54.5	+420	24	35.5	+36	20	38	+114	475
48	96	70	−448	22	49	+323	−12	43.5	+335	24	35.5	+36	28	46.5	+140	386
49	100	77	−493	21	47.5	+313	0	54.5	+420	22	33	+33	34	53	+159	432
50	88	62	−397	14	35	+231	− 8	47	+362	32	44.5	+45	18	35.5	+107	348
51	88	62	−397	25	53	+350	− 4	51	+393	16	27.5	+28	16	33	+ 99	473
52	80	54.5	−349	21	47.5	+313	− 4	51	+393	32	44.5	+45	22	40	+120	522
53	92	65.5	−419	16	39.5	+261	− 4	51	+393	22	33	+33	32	51	+153	421
54	78	52	−333	24	52.5	+347	0	54.5	+420	36	47.5	+48	18	35.5	+107	589
55	86	60	−384	19	44	+290	− 8	47	+362	34	46	+46	24	42.5	+128	442
56	90	63.7	−408	16	39.5	+261	+ 4	58	+447	18	29	+29	16	33	+ 99	428
57	84	58.5	−374	23	51	+337	+ 4	58	+447	34	46	+46	28	46.5	+140	597
58	96	70	−448	18	42.5	+281	+12	66	+508	20	31	+31	26	44.5	+134	506
59	90	63.7	−408	22	49	+323	−16	40	+308	18	29	+29	28	46.5	+140	392
60	100	77	−493	26	54	+356	− 4	51	+393	32	44.5	+45	32	51	+153	454
61	92	65.5	−419	21	47.5	+313	− 4	51	+393	32	44.5	+45	28	46.5	+140	472
62	94	67.5	−432	27	55	+363	−12	43.5	+335	34	46	+46	30	49	+147	459
63	100	77	−493	21	47.5	+313	+ 8	62.5	+481	40	51.5	+52	34	53	+159	512
64	74	48	−307	23	51	+337	− 8	47	+362	32	44.5	+45	20	38	+114	551
65	84	58.5	−374	20	46	+304	−12	43.5	+335	38	49	+49	32	51	+153	467
66	92	65.5	−419	25	53	+350	4	58	+447	28	40.5	+41	24	42.5	+128	547
67	82	56	−358	24	52.5	+347	− 4	51	+393	38	49	+49	24	42.5	+128	559
68	90	63.7	−408	13	33	+218	8	62.5	+481	28	40.5	+41	26	44.5	+134	466
69	94	67.5	−432	35	63	+416	− 4	51	+393	44	55	+55	34	53	+159	591
70	94	67.5	−432	41	67.4	+445	−24	32.5	+250	36	47.5	+48	28	46.5	+140	451
71	92	65.5	−419	22	49	+323	−12	43.5	+335	40	51.5	+52	42	58	+174	465
72	96	70	−448	15	37	+244	−24	32.5	+250	38	49	+49	52	65.5	+197	292
73	80	54.5	−349	18	42.5	+281	−24	32.5	+250	36	47.5	+48	32	51	+153	383
74	78	52	−333	21	47.5	+313	−12	43.5	+335	60	67	+67	44	59.5	+179	561
75	86	60	−384	25	53	+350	−16	40	+308	34	46	+46	28	46.5	+140	460
76	86	60	−384	15	37	+244	4	58	+447	36	47.5	+48	48	62	+186	541
77	92	65.5	−419	30	58	+382	0	54.5	+420	28	40.5	+41	26	44.5	+134	558

N = 77

SCORING ORGANIC EFFICIENCY—AVERAGE GROUP—FRESHMEN

Subject	Sitting Diastolic Pressure			Breath-Holding 20 secs. after exercise			Difference between Standing P.R. & P.R. 2 mins. after exercise			Sitting Pulse Pressure			Standing Pulse Pressure			Total
	Pressure	T-Score	T-Score × −6.4	B.H.	T-Score	T-Score × +6.6	Pulse Rate Diff.	T-Score	T-Score × +7.7	Pulse Press.	T-Score	T-Score × +1.0	Pulse Press.	T-Score	T-Score × +3.0	
1	72	46	−294	14	35	+231	+10	64	+493	37	48	+48	27	45	+135	613
2	80	54.5	−349	25	53	+350	+11	65	+501	47	57	+57	39	56	+168	727
3	84	58.5	−374	28	56.5	+373	−16	40	+308	38	49	+49	34	53	+159	515
4	78	52	−333	26	54	+356	+11	65	+501	58	66	+66	52	65.5	+197	787
5	90	64	−410	18	42.5	+281	− 9	46	+354	40	51.5	+52	38	55.5	+167	444
6	82	56	−358	15	37	+244	−20	36	+277	28	40.5	+41	24	42.5	+128	332
7	80	54.5	−349	22	49	+323	−23	33	+254	30	42	+42	16	33	+ 99	369
8	80	54.5	−349	24	52.5	+347	−15	41	+316	24	35.5	+36	22	40	+120	470
9	70	43.5	−278	23	51	+337	−13	43	+331	40	51.5	+52	35	54	+162	604
10	74	48	−307	25	53	+350	+ 1	55	+424	56	65	+65	60	70	+210	742
11	75	49	−314	32	60.5	+399	−22	34	+262	49	58	+58	31	50	+150	555
12	74	48	−307	34	62	+409	− 3	52	+400	36	47.5	+48	32	51	+153	703
13	76	50.5	−323	51	72	+475	−14	42	+323	54	63	+63	40	57	+171	709
14	82	56	−358	15	37	+244	+ 5	59	+454	40	51.5	+52	15	32	+ 96	488
15	86	60	−384	21	47.5	+314	−14	42	+323	32	44.5	+45	36	54.5	+164	462
16	78	52	−333	23	51	+337	−17	39	+300	22	33	+33	22	40	+120	457
17	90	64	−410	23	51	+337	−11	44	+339	20	31	+31	23	41	+123	420
18	74	48	−307	29	57	+376	−33	22	+169	34	46	+46	24	42.5	+128	412
19	62	35	−224	24	52.5	+347	+ 4	58	+447	53	62	+62	28	46.5	+140	772
20	58	31	−198	24	52.5	+347	−12	43.5	+335	60	67	+67	48	62	+186	737
21	74	48	−307	21	47.5	+314	− 2	53	+408	50	59	+59	40	57	+171	645
22	68	41	−262	26	54	+356	−16	40	+308	48	57.5	+58	30	49	+147	607
23	73	47	−301	17	41	+271	−19	37	+285	57	65.5	+66	45	60	+180	501
24	62	35	−224	25	53	+350	−19	37	+285	49	58	+58	51	64	+192	661
25	68	41	−262	16	39.5	+261	− 1	54	+416	50	59	+59	39	56	+168	642
26	82	56	−358	24	52.5	+347	+18	69.5	+535	42	53	+53	29	48	+144	721

25	68	41	−262	16	39.5	+261	−1	54	+410	30	39	+39	39	36	+288	721
26	82	56	−358	24	52.5	+347	+18	69.5	+535	42	53	+53	29	48	+144	721
27	82	56	−358	32	60.5	+399	−28	28	+216	36	47.5	+48	26	44.5	+134	439
28	53	24	−154	37	65	+429	0	54.5	+420	50	59	+59	29	48	+144	898
29	80	54.5	−349	20	46	+304	+ 6	60	+462	32	44.5	+45	31	50	+150	612
30	72	46	−294	22	49	+323	+ 8	62.5	+481	51	60	+60	35	54	+162	732
31	82	56	−358	26	54	+356	+ 3	57	+439	26	38	+38	23	41	+123	598
32	63	36	−230	18	42.5	+281	+ 9	63	+485	49	58	+58	33	52	+156	750
33	76	50.5	−323	29	57	+376	− 7	48	+370	42	53	+53	36	54.5	+164	640
34	74	48	−307	22	49	+323	− 7	48	+370	46	56	+56	36	54.5	+164	606
35	80	54.5	−349	23	51	+337	− 2	53	+408	38	49	+49	36	54.5	+164	609
36	76	50.5	−323	19	44	+290	− 8	47	+362	36	47.5	+48	27	45	+135	512
37	58	31	−198	36	64	+422	−25	31	+239	40	51.5	+52	36	54.5	+164	679
38	98	74	−474	23	51	+337	− 4	51	+393	22	33	+33	18	35.5	+107	396
39	77	51	−326	27	55	+363	− 6	49	+377	26	38	+38	21	39	+117	569
40	70	43.5	−278	23	51	+337	+16	68.5	+527	52	61	+61	38	55.5	+167	814
41	72	46	−294	16	39.5	+261	−13	43	+331	30	42	+42	19	36	+108	448
42	77	51	−326	26	54	+356	−12	43.5	+335	31	43	+43	18	35.5	+107	515
43	75	49	−314	28	56.5	+373	−18	38	+293	33	45	+45	28	46.5	+140	537
44	67	40	−256	17	41	+271	−13	43	+331	38	49	+49	24	42.5	+128	523
45	72	46	−294	37	65	+429	−20	36	+277	30	42	+42	21	39	+117	571
46	86	60	−384	30	58	+383	− 9	46	+354	19	30	+30	11	27	+ 81	464
47	74	48	−307	29	57	+376	−18	38	+293	34	46	+46	32	51	+153	561
48	78	52	−333	20	46	+304	+ 2	56	+431	47	57	+57	31	50	+150	609
49	88	62	−397	26	54	+356	+ 3	57	+439	52	61	+61	56	68	+204	663
50	70	43.5	−278	21	47.5	+314	0	54.5	+420	46	56	+56	32	51	+153	665
51	70	43.5	−278	28	56.5	+373	− 7	48	+370	36	47.5	+48	30	49	+147	660
52	82	56	−358	31	59	+389	−13	43	+331	26	38	+38	22	40	+120	520
53	62	35	−224	25	53	+350	−17	39	+300	43	54	+54	20	38	+114	594
54	82	56	−358	15	37	+244	− 6	49	+377	68	71	+71	67	75	+225	559
55	75	49	−314	30	58	+383	+ 8	62.5	+481	53	62	+62	32	51	+153	765
56	70	43.5	−278	19	44	+290	− 7	48	+370	40	51.5	+52	29	48	+144	578
57	52	23	−147	21	47.5	+314	−15	41	+316	60	67	+67	32	51	+153	703
58	74	48	−307	27	55	+363	+17	69	+531	56	65	+65	50	63	+189	841
59	73	47	−301	20	46	+304	+ 8	62.5	+481	53	62	+62	32	51	+153	699
60	70	43.5	−278	31	59	+389	−24	32.5	+250	31	43	+43	28	46.5	+140	544

SCORING ORGANIC EFFICIENCY—AVERAGE GROUP—FRESHMEN—(*Continued*)

Subject	Sitting Diastolic Pressure			Breath-Holding 20 secs. after exercise			Difference between Standing P.R. & P.R. 2 mins. after exercise			Sitting Pulse Pressure			Standing Pulse Pressure			Total
	Pressure	T-Score	T-Score × —6.4	B.H.	T-Score	T-Score × +6.6	Pulse Rate Diff.	T-Score	T-Score × +7.7	Pulse Press.	T-Score	T-Score × +1.0	Pulse Press.	T-Score	T-Score × +3.0	
61	76	50.5	—323	20	46	+304	—12	43.5	+335	24	35.5	+36	20	38	+114	466
62	68	41	—262	22	49	+323	—16	40	+308	40	51.5	+52	22	40	+120	541
63	82	56	—358	18	42.5	+281	+ 5	59	+454	42	53	+53	36	54.5	+164	594
64	78	52	—333	38	65.5	+432	—25	31	+239	42	53	+53	26	44.5	+134	525
65	72	46	—294	18	42.5	+281	—16	40	+308	60	67	+67	48	62	+186	548
66	66	39	—250	23	51	+337	+ 5	59	+454	31	43	+43	23	41	+123	707
67	72	46	—294	22	49	+323	+ 9	63	+485	46	56	+56	46	60.5	+182	752
68	72	46	—294	24	52.5	+347	+16	68.5	+527	56	65	+65	49	62.5	+188	833
69	83	57	—365	32	60.5	+399	0	54.5	+420	47	57	+57	40	57	+171	682
70	70	43.5	—278	31	59	+389	—17	39	+300	47	57	+57	36	54.5	+164	632
71	79	53	—339	30	58	+383	— 9	46	+354	55	64	+64	38	55.5	+167	629
72	68	41	—262	23	51	+337	+11	65	+500	41	52	+52	26	44.5	+134	761
73	82	56	—358	26	54	+356	—16	40	+308	42	53	+53	30	49	+147	506
74	69	42	—269	12	31.5	+208	0	54.5	+420	34	46	+46	20	38	+114	519
75	72	46	—294	34	62	+409	0	54.5	+420	34	46	+46	44	59.5	+179	760
76	65	38	—243	18	42.5	+281	—10	45	+347	35	47	+47	34	53	+159	591
77	73	47	—301	20	46	+304	— 3	52	+400	43	54	+54	35	54	+162	619
78	70	43.5	—278	23	51	+337	+ 3	57	+439	58	66	+66	50	63	+189	753
79	74	48	—307	35	63	+416	— 6	49	+377	26	38	+38	22	40	+120	644
80	67	40	—256	13	33	+218	— 8	47	+362	39	50	+50	26	44.5	+134	508
81	68	41	—262	24	52.5	+347	—11	44	+339	32	44.5	+45	30	49	+147	616
82	75	49	—314	23	51	+337	+ 2	56	+431	38	49	+49	24	42.5	+128	631
83	70	43.5	—278	32	60.5	+399	+ 8	62.5	+481	37	48	+48	42	58	+174	824
84	65	38	—243	22	49	+323	—21	35	+270	30	42	+42	24	42.5	+128	520
85	78	52	—333	16	39.5	+261	—12	43.5	+335	38	49	+49	43	59	+177	489
86	62	35	—224	20	46	+304	— 3	52	+400	40	51.5	+52	23	41	+123	655
87	70	43.5	—278	25	53	+350	0	54.5	+420	40	51.5	+52	30	49	+147	691
88	84	58.5	—374	24	52.5	+347	— 7	48	+370	44	55	+55	38	55.5	+167	565
89	65	38	—243	30	58	+383	+ 2	56	+431	45	55.5	+56	33	52	+156	783
92	76	50.5	—323	15	37	+244	— 4	51	+393	46	56	+56	30	49	+147	517
93	94	67	—429	15	37	+244	—11	44	+339	23	34	+34	23	41	+123	311
94	80	54.5	—349	17	41	+271	—17	39	+300	32	44.5	+45	26	44.5	+134	401

88	84	58.5	—374	14	58	+383	+ 2	56	+431	45	55.5	+56	33	52	+156	703
89	65	38	—243	30	58	+383	—15	42	+316	44	55	+55	26	44.5	+134	559
90	88	62	—397	20	46	+304	— 5	50	+385	44	55	+55	33	52	+156	622
91	88	62	—397	25	53	+350	+10	64	+493	24	35.5	+36	21	39	+117	673
92	76	50.5	—323	15	37	+244	— 4	51	+393	46	56	+56	30	49	+147	517
93	94	67	—429	15	37	+244	—11	44	+339	23	34	+34	23	41	+123	311
94	80	54.5	—349	17	41	+271	—17	39	+300	32	44.5	+45	26	44.5	+134	401
95	80	54.5	—349	24	52.5	+347	—13	43	+331	30	42	+42	16	33	+ 99	470
96	72	46	—294	12	31.5	+208	—22	34	+262	28	40.5	+41	23	41	+123	340
97	70	43.5	—278	25	53	+350	— 6	49	+377	48	57.5	+58	28	46.5	+140	647
98	80	54.5	—349	41	67.4	+445	— 5	50	+385	26	38	+38	37	55	+165	684
99	76	50.5	—323	23	51	+337	— 4	51	+393	36	47.5	+48	24	42.5	+128	583
100	67	40	—256	22	49	+323	—21	35	+270	47	57	+57	43	59	+177	571
101	68	41	—262	12	31.5	+208	+ 6	60	+462	40	51.5	+52	42	58	+174	634
102	69	42	—269	26	54	+356	— 4	51	+393	39	50	+50	37	55	+165	695
103	75	49	—314	22	49	+323	—17	39	+300	59	66.5	+67	55	67	+201	577
104	66	39	—250	30	58	+383	—18	38	+293	42	53	+53	24	42.5	+128	607
105	56	29	—186	36	64	+422	+13	66.5	+512	44	55	+55	32	51	+153	956
106	79	53	—339	23	51	+337	0	54.5	+420	33	45	+45	28	46.5	+140	603
107	73	47	—301	31	59	+389	—11	44	+339	41	52	+52	34	53	+159	638
108	74	48	—307	26	54	+356	+ 2	56	+431	56	65	+65	45	60	+180	725
109	80	54.5	—349	39	66	+435	0	54.5	+420	35	47	+47	35	54	+162	715
110	80	54.5	—349	35	63	+416	—13	43	+331	40	51.5	+52	40	57	+171	621
111	80	54.5	—349	35	63	+416	+ 8	62.5	+481	52	61	+61	55	67	+201	810
112	63	36	—230	19	44	+290	— 6	49	+377	39	50	+50	37	55	+165	652
113	76	50.5	—323	25	53	+350	— 7	48	+370	34	46	+46	29	48	+144	587
114	85	59	—378	16	39.5	+261	—13	43	+331	27	39	+39	19	36	+108	361
115	72	46	—294	30	58	+383	— 8	47	+362	50	59	+59	38	55.5	+167	677
116	82	56	—358	19	44	+290	+ 5	59	+454	45	55.5	+56	33	52	+156	598
117	84	58.5	—374	31	59	+389	— 6	49	+377	50	59	+59	43	59	+177	628
118	73	47	—301	19	44	+290	+12	66	+508	37	48	+48	21	39	+117	662
119	73	47	—301	25	53	+350	— 8	47	+362	42	53	+53	48	62	+186	650
120	70	43.5	—278	20	46	+304	— 5	50	+385	44	55	+55	33	52	+156	622
121	76	50.5	—323	25	53	+350	+10	64	+493	24	35.5	+36	21	39	+117	673
122	62	35	—224	37	65	+429	—22	34	+262	41	52	+52	34	53	+159	678
123	78	52	—333	23	51	+337	— 9	46	+354	36	47.5	+48	20	38	+114	520
124	74	48	—307	28	56.5	+373	+11	65	+500	46	56	+56	49	62.5	+188	810
125	74	48	—307	23	51	+337	—16	40	+308	26	38	+38	27	45	+135	511
126	76	50.5	—323	19	44	+290	—21	35	+270	40	51.5	+52	38	55.5	+167	456
127	63	36	—230	17	41	+271	—17	39	+300	28	40.5	+41	29	48	+144	526
128	88	62	—397	21	47.5	+314	—13	43	+331	32	44.5	+45	34	53	+159	452
129	63	36	—230	25	53	+350	— 8	47	+362	73	75	+75	62	71	+213	770
130	77	51	—326	31	59	+389	—12	43	+335	35	47	+47	35	54	+162	607
131	82	56	—358	29	57	+376	— 2	53	+408	32	44.5	+45	30	49	+147	618

SCORING ORGANIC EFFICIENCY—AVERAGE GROUP—FRESHMEN—(*Continued*)

Subject	Sitting Diastolic Pressure			Breath-Holding 20 secs. after exercise			Difference between Standing P.R. & P.R. 2 mins. after exercise			Sitting Pulse Pressure			Standing Pulse Pressure			Total
	Pressure	T-Score	T-Score × −6.4	B.H.	T-Score	T-Score × +6.6	Pulse Rate Diff.	T-Score	T-Score × +7.7	Pulse Press.	T-Score	T-Score × +1.0	Pulse Press.	T-Score	T-Score × +3.0	
132	72	46	−294	32	60.5	+399	−19	37	+285	44	55	+55	30	49	+147	592
133	65	38	−243	20	46	+304	− 8	47	+362	55	64	+64	42	58	+174	661
134	70	43.5	−278	33	61	+403	−21	35	+270	43	54	+54	30	49	+147	596
135	61	34	−278	23	51	+337	− 2	53	+408	59	66.5	+67	49	62.5	+188	722
136	75	49	−314	14	35	+231	− 6	49	+377	45	55.5	+56	28	46.5	+140	490
137	60	33	−211	31	59	+389	−15	41	+316	78	78	+78	74	80	+240	812
138	82	56	−358	50	71.5	+472	− 7	48	+370	34	46	+46	34	53	+159	689
139	78	52	−333	23	51	+337	0	54.5	+420	50	59	+59	44	59.5	+179	662
140	80	54.5	−349	23	51	+337	−15	41	+316	32	44.5	+45	28	46.5	+140	489
141	74	48	−307	16	39.5	+261	− 7	48	+370	30	42	+42	17	34	+102	468
142	84	58.5	−374	18	42.5	+281	+ 8	62.5	+481	28	40.5	+41	26	44.5	+134	563
143	74	48	−307	23	51	+337	−18	38	+293	38	49	+49	31	50	+150	522
144	72	46	−294	18	42.5	+281	0	54.5	+420	40	51.5	+52	27	45	+135	594
145	78	52	−333	40	67	+429	− 2	53	+408	19	30	+30	14	30.5	+ 92	626
146	73	47	−301	41	67.4	+445	−30	25	+193	37	48	+48	24	42.5	+128	513
147	72	46	−294	21	47.5	+314	− 3	52	+400	50	59	+59	32	51	+153	632
148	70	43.5	−278	22	49	+323	+ 2	56	+431	50	59	+59	47	61	+183	718
149	83	57	−365	22	49	+323	− 7	48	+370	23	34	+34	19	36	+108	470
150	72	46	−294	28	56.5	+373	−12	43.5	+335	33	45	+45	26	44.5	+134	593
151	66	39	−250	49	71	+454	−28	28	+216	39	50	+50	36	54.5	+164	634
152	72	46	−294	15	37	+244	+ 2	56	+431	68	71	+71	56	68	+204	656
153	76	50.5	−323	16	39.5	+261	+11	65	+500	32	44.5	+45	29	48	+144	627
154	64	37	−237	17	41	+271	− 4	51	+393	74	76	+76	52	65.5	+197	700
155	74	48	−307	28	56.5	+373	− 6	49	+377	38	49	+49	30	49	+147	639
156	80	54.5	−349	20	46	+304	− 9	46	+354	26	38	+38	22	40	+120	467
157	80	54.5	−349	31	59	+389	−12	43.5	+335	40	51.5	+52	30	49	+147	574
158	82	56	−358	41	67.4	+445	− 4	51	+393	28	41.5	+41	28	46.5	+140	661
159	84	58.5	−374	27	55	+363	+ 2	56	+431	52	61	+61	44	59.5	+179	660
160	84	58.5	−374	19	44	+290	− 6	49	+377	24	35.5	+36	27	45	+135	464
161	64	37	−237	18	42.5	+281	− 4	51	+393	48	57.5	+58	34	53	+159	654

SCORING ORGANIC EFFICIENCY WITH WEIGHTED T-SCALE
Swimmers—"Good" Condition

Subject	Sitting Diastolic Pressure			Breath-Holding 20 secs. after exercise			Difference between Standing P.R. & P.R. 2 mins. after exercise			Sitting Pulse Pressure			Standing Pulse Pressure			Total
	Pressure	T-Score	T-Score × −6.4	B.H.	T-Score	T-Score × +6.6	Pulse Rate Diff.	T-Score	T-Score × +7.7	Pulse Press.	T-Score	T-Score × +1.0	Pulse Press.	T-Score	T-Score × +3.0	
1	85	59	−378	22	49	+323	+16	68.5	+527	30	42	+42	30	49	+147	661
2	74	48	−307	28	56.5	+373	+ 8	62.5	+481	30	42	+42	19	36	+108	697
3	85	59	−378	35	63	+416	+ 4	58	+447	30	42	+42	30	49	+147	674
4	72	46	−294	22	49	+323	−12	43.5	+335	48	57.5	+58	28	46.5	+140	562
5	75	49	−314	20	46	+304	+ 8	62.5	+481	55	64	+64	34	53	+159	694
6	74	48	−307	40	67	+422	− 8	47	+362	46	56	+56	43	59	+177	710
7	85	59	−378	24	52.5	+347	+16	68.5	+527	35	47	+47	35	54	+162	705
8	95	69	−442	36	64	+422	+ 4	58	+447	28	40.5	+41	30	49	+147	615
9	78	52	−333	32	60.5	+400	+16	68.5	+527	38	49	+49	39	56	+168	811
10	78	52	−333	34	62	+409	+ 4	58	+447	30	42	+42	20	38	+114	679
11	73	47	−301	25	53	+350	+12	66	+508	48	57.5	+58	37	55	+165	780
12	75	49	−314	35	63	+416	+ 4	58	+447	40	51.5	+52	18	35.5	+107	708
13	73	47	−301	33	61	+403	− 4	51	+393	37	48	+48	23	41	+123	666
14	78	52	−333	23	51	+337	+ 8	62.5	+481	40	51.5	+52	30	49	+147	684
15	85	59	−378	31	59	+389	+16	68.5	+527	18	29	+29	20	38	+114	681
16	86	60	−384	29	57	+376	+ 4	58	+447	33	45	+45	25	43	+129	613
17	84	58.5	−374	56	75.5	+498	−16	40	+308	66	70	+70	51	64	+192	694
18	78	52	−333	24	52.5	+347	0	54.5	+420	54	63	+63	38	55.5	+167	664
19	85	59	−378	32	60.5	+400	− 4	51	+393	45	55.5	+56	48	62	+186	657
20	84	58.5	−374	21	47.5	+314	+ 8	62.5	+481	43	54	+54	34	53	+159	634
21	78	52	−333	48	70.5	+465	0	54.5	+420	52	61	+61	35	54	+162	775
22	74	48	−307	21	47.5	+314	+ 4	58	+447	50	59	+59	45	60	+180	693
23	74	48	−307	22	49	+323	− 4	51	+393	51	60	+60	36	54.5	+164	633
24	78	52	−333	36	64	+422	− 8	47	+362	37	48	+48	26	44.5	+134	633
25	84	58.5	−374	22	49	+323	+ 4	58	+447	39	50	+50	42	58	+174	620

SCORING ORGANIC EFFICIENCY WITH WEIGHTED T-SCALE—SWIMMERS—(*Continued*)

Subject	Sitting Diastolic Pressure			Breath-Holding 20 secs. after exercise			Difference between Standing P.R. & P.R. 2 mins. after exercise			Sitting Pulse Pressure			Standing Pulse Pressure			Total
	Pressure	T-Score	T-Score × −6.4	B.H.	T-Score	T-Score × +6.6	Pulse Rate Diff.	T-Score	T-Score × +7.7	Pulse Press.	T-Score	T-Score × +1.0	Pulse Press.	T-Score	T-Score × +3.0	
26	83	57	−365	42	67.8	+447	− 4	51	+393	45	55.5	+56	30	49	+147	678
27	65	38	−243	20	46	+304	+10	64	+493	55	64	+64	50	63	+189	807
28	78	52	−333	50	71.5	+472	+24	71	+547	52	61	+61	57	68.5	+206	953
29	72	46	−294	26	54	+356	0	54.5	+420	70	72.5	+73	64	72.5	+218	773
30	68	41	−262	26	54	+356	+ 8	62.5	+481	52	61	+61	40	57	+171	807
31	65	38	−243	58	75.5	+498	4	58	+447	55	64	+64	40	57	+171	937
32	70	43.5	−278	37	65	+429	0	54.5	+420	55	64	+64	55	67	+201	836
33	75	49	−314	33	61	+403	− 4	51	+393	30	42	+42	40	57	+171	695
34	70	43.5	−278	30	58	+383	+ 4	58	+447	55	64	+64	35	54	+162	778
35	80	54.5	−349	30	58	+383	+ 8	62.5	+481	53	62	+62	45	60	+180	757
36	78	52	−333	25	53	+350	0	54.5	+420	52	61	+61	53	66	+198	696
37	75	49	−314	31	59	+389	− 8	47	+362	55	64	+64	48	62	+186	687
38	70	43.5	−278	32	60.5	+400	− 8	47	+362	50	59	+59	50	63	+189	732
39	82	56	−358	59	75.5	+498	+ 8	62.5	+481	40	51.5	+52	40	57	+171	844
40	70	43.5	−278	39	66	+436	− 8	47	+362	50	59	+59	25	43	+129	708
41	80	54.5	−349	24	52.5	+347	+ 8	62.5	+481	40	51.5	+52	35	54	+162	693
42	68	41	−262	37	65	+429	− 5	50	+385	42	53	+53	30	49	+147	752
43	85	59	−378	27	55	+363	0	54.5	+420	55	64	+64	40	57	+171	640
44	72	46	−294	33	61	+403	− 4	51	+393	48	57.5	+58	35	54	+162	722
45	83	57	−365	48	70.5	+465	0	54.5	+420	42	53	+53	57	68.5	+206	779
46	77	51	−326	27	55	+363	0	54.5	+420	43	54	+54	32	51	+153	664
N = 46																

RELIABILITY COEFFICIENT FOR "ORGANIC EFFICIENCY TEST"
Method—Bi-Serial R[1]

Range	"Poor" Condition	"Good" Condition	Total
940	..	1	1
920	..	1	1
900	..	..	..
880	..	..	..
860	..	..	..
840	..	1	1
820	..	1	1
800	..	3	3
780	..	2	2
760	..	3	3
740	..	2	2
720	..	2	2
700	..	4	4
680	1	10	11
660	..	7	7
640	..	2	2
620	..	4	4
600	2	2	4
580	6	..	6
560	3	1	4
540	12	..	12
520	3	..	3
500	8	..	8
480	3	..	3
460	10	..	10
440	9	..	9
420	5	..	5
400	2	..	2
380	5	..	5
360	3	..	3
340	1	..	1
320	1	..	1
300	1	..	1
280	1	..	1
260	1	..	1
	$N_1 = 77$	$N_2 = 46$	$N = 123$

$$\frac{n_1}{N} = q = \frac{77}{123} = .6260$$

$$\frac{n_2}{N} = p = \frac{46}{123} = .3740$$

$$M_1 = 478.00$$

$$M_2 = 720.12$$

$$\sigma_y = 137.40$$

$$r_{bis} = \frac{M_2 - M_1}{\sigma_y}\sqrt{pq}$$

$$r_{bis} = \frac{720.12 - 478.00}{137.40}\sqrt{.63 \times .37}$$

$$r_{bis} = \frac{116.2176}{137.4}$$

$$r_{bis} = .845$$

[1] Richardson and Stalnaker, "A Note on the Use of the Bi-Serial *R* in Test Research," *Journal of General Psychology*, VIII: 20 (April, 1933), 463-5.

APPENDIX II

SUMMARY OF CORRELATIONS BETWEEN INFIRMARY GROUP ("POOR" CONDITION) AND SWIMMING GROUP ("GOOD" CONDITION)

Test Items	*Raw Correlations*
1. Horizontal pulse rate	+.110
2. Sitting pulse rate	—.200
3. Standing pulse rate	—.103
4. Horizontal systolic pressure	+.065
5. Sitting systolic pressure	—.015
6. Standing systolic pressure	+.190
7. Horizontal diastolic pressure	—.043
8. Sitting diastolic pressure	—.622
9. Standing diastolic pressure	—.350
10. Horizontal pulse pressure	+.250
11. Sitting pulse pressure	+.414
12. Standing pulse pressure	+.346
13. Normal breath-holding	+.174
14. Vital capacity with temperature correlation	+.311
15. Pulse rate immediately following exercise	+.174
16. Breath-holding 20 seconds after exercise	+.531
17. Pulse rate (sitting) 1½ minutes after exercise	+.212
18. Pulse rate (standing) 2 minutes after exercise	+.352
19. Difference between horizontal and standing pulse rates	—.241
20. Difference between horizontal and standing systolic pressure	+.140
21. Difference between horizontal and standing diastolic pressure	—.263
22. Difference between horizontal and standing pulse pressure	+.204
23. Difference between normal breath-holding and breath-holding after exercise	—.178
24. Difference between normal standing pulse rate and pulse rate after exercise	+.243
25. Difference between normal sitting pulse rate and pulse rate 1½ minutes after exercise	+.303
26. Difference between normal standing pulse rate and pulse rate 2 minutes after exercise	+.446

APPENDIX III

STATISTICAL METHOD FOR "ORGANIC TEST" DEVELOPMENT

Content:

1. Criterion correlations in "Organic Efficiency Test."
2. Partial correlations in "Organic Efficiency Test."
3. Fisher-Doolittle method for solving the multiple correlation for the "Organic Efficiency Test."

Criterion Correlations Using 1933–35 Data—Total Data

Method—Bi-Serial *R*

0. Condition (Varsity swimmers tested on ability to swim 440 yards).		
1. Sitting diastolic pressure	—.622	
2. Breath-holding 20 seconds after standard exercise	+.531	
3. Difference between pulse rate normal and pulse rate 2 minutes after exercise	+.446	
4. Sitting pulse pressure	+.414	
5. Standing pulse pressure	+.346	

Partial Correlations

Method—Product Moment—Scatter Diagram

$r_{12} = -.270$

$r_{20} = +.091$

$r_{13} = -.095$ $\quad r_{24} = +.254$ $\quad r_{34} = +.014$ $\quad r_{25} = +.686$

$r_{14} = -.544$ $\quad r_{35} = +.041$

$r_{25} = +.192$

$r_{15} = -.267$

MULTIPLE CORRELATION—FISHER-DOOLITTLE METHOD

	1	2	3	4	5	Σ
$A_1 = C_1 =$ Eq. 1	1.000	.270	.095	.544	.267	2.176
$D_1 = C_1 (\frac{-1}{C_{11}})$	—1.000	—.270	—.095	—.544	—.267	—2.176
$A_2 =$ Eq. 2	.270	1.000	.091	.254	.192	1.807
$B_{1-2} = C_1(D_{12})$		—.0729	.0256	—.1468	—.0721	—.5875
$C_2 = A_2 + B_{1-2}$		.9271	.0654	.1072	.1199	1.2195
$D_2 = C_2 (\frac{-1}{C_{22}})$		—1.000	—.0705	—.1156	—.1293	1.3153
$A_3 =$ Eq. 3	.095	.091	1.000	.014	.041	1.241
$B_{1-3} = C_1(D_{13})$			—.0090	—.0517	—.0254	—.2067
$B_{2-3} = C_2(D_{23})$			—.0046	—.0076	—.0085	—.0860
$C_3 = A_3 + \Sigma B_{1-3}$			.9864	—.0453	.0071	.9483
$D_3 = C_3 (\frac{-1}{C_{33}})$			—1.000	.0459	.0072	.9613
$A_4 =$ Eq. 4	.544	.254	.014	1.000	.686	2.498
$B_{1-4} = C_1(D_{14})$				—.2959	—.1452	—1.1837
$B_{2-4} = C_2(D_{24})$				—.0124	—.0139	—.1410
$B_{3-4} = C_3(D_{34})$				—.0021	+.0003	+.0435
$C_4 = A_4 + \Sigma B_{1-4}$				.6896	.5272	1.2168
$D_4 = C_4 (\frac{-1}{C_{44}})$				—1.000	—.7645	—1.7645
$A_5 =$ Eq. 5	.267	.192	.041	.686	1.000	2.186
$B_{1-5} = C_1(D_{15})$					—.0713	—.5810
$B_{2-5} = C_2(D_{25})$					—.0155	—.1577
$B_{3-5} = C_3(D_{35})$					—.0001	—.0068
$B_{4-5} = C_4(D_{45})$					—.4030	—.9302
$C_5 = A_5 + \Sigma B_{1-5}$					.5101	.5103
$D_5 = C_5 (\frac{-1}{C_{55}})$ *Weights*	—6.4	+6.6	+7.7	+1	—1.000 +3.0	—1.0003
$A_0 =$ Eq. 0	.622	.531	.446	.414	.346	
$B_1 = \Sigma_1 r_{01} R_{1j}$	.403	.415	.485	.063	.181	r_m=.881

	R_{1j}	1	2	3	4	5	$1/C_{11}$
	1	1.5232	—.2089	—.1248	—.9932	+.3198	1.0000
	2	—.2089	1.1068	—.0762	—.1154	—.0744	1.0786
$N = 130$	3	—.1248	—.0762	+1.0203	+.1299	—.0829	1.0137
	4	—.9932	—.1154	+.1299	+2.5958	+1.4987	1.4501
	5	+.3198	—.0744	—.0829	—1.4987	1.9604	1.9604

The Effect of Basketball, Wrestling, and Swimming upon the White Blood Corpuscles

By Peter V. Karpovich, M.D.
Professor of Physiology, Springfield College

FOR THE past ten years there has been an increasing interest in the changes in the white blood corpuscles induced by physical exercises.

According to Egoroff (1926) these changes may be divided into three groups:

1. Lymphocytic phase, characterized by an increase in lymphocytes up to 55 per cent. Appears after an exercise of short duration.

2. Neutrophilic phase, characterized by an increase in neutrophiles sometimes to 78 per cent with a "shift to the left" (a greater increase of the young, non-segmented neutrophiles than older, segmented) and lymphopenia. This phase immediately follows the first, usually develops during exercises requiring a considerable amount of energy (running 10,000 meters).

3. Intoxication phase, which is subdivided into: regenerative and degenerative types. The regenerative is merely a higher degree of the neutrophilic phase. The neutrophiles may rise to 90 per cent, the shift to the left is greater, the lymphocytes may drop to 5 per cent, eosinophiles disappear entirely. This type develops after exercise of a great intensity (marathon). The degenerative type has a marked drop in the total number of the white blood corpuscles. With the exception of the neutrophiles, the percentage of all other corpuscles decreases. The shift to the left is less than in regenerative type. On the whole this type resembles very much the blood picture in some serious diseases where prognosis is unfavorable. The degenerative type develops after strenuous exercises undertaken by persons in poor health condition.

Egoroff asserts that the morphological picture of the blood can give an indication as to the degree of fatigue and the degree of training. Egoroff's classification was tried by Krestovnikoff (1927), Bortchaninova and co-workers (1927). They found that this classification was applicable to groups only and not to individuals. Krestovnikoff could not find any relation between the kind of exercise, amount of work, and the shift to the left, although he states that less trained athletes showed a greater per cent decrease in lymphocytes than the better trained athletes. Bortchaninova and her co-workers agree with Egoroff that there is a relation between the intensity of work and the

changes in the differential count of the blood corpuscles. The greater the intensity of work, the greater the changes in per cent of lymphocytes and leucocytes, but the shift to the left seems to have no relation to the intensity of work. The women in general showed a weaker cellular reaction than the men, although there were a few exceptions in running distances of 3000 and 5000 meters. Hartman and Jokl (1930) observed changes approximately the same as described by Egoroff in his first two phases. They also indicated that the changes in the morphological composition of the blood are similar to those appearing after an injection of adrenalin.

Jokl (1931) found that a run of 25 kilometers produced a high degree neutrophilic phase. After 42.2 kilometers run, the percentile change was less noticeable. A 400-meter run gave a typical lymphocytic phase. Observations by Thörner on the Olympic contestants in Amsterdam, furnished material showing that exercise of short duration produces a lymphocytic phase followed by a neutrophilic phase with a shift to the left.

All these references clearly show that muscular exercises affect the morphological composition of the blood. It is possible to state that there is a certain relation between the intensity of exercise and the change in the blood.

The aim of the present investigation was to study the effect produced by some popular sports like basketball, wrestling, and swimming.

EFFECT OF CERTAIN ACTIVITIES UPON THE BLOOD PICTURE

Effect of Basketball (Table I).—The time of participation varied from eight to twenty minutes. Blood samples were taken during intercollegiate and campus competition. Most of the men were well-trained varsity players. The reaction of the blood was obviously neutrophilic. Monocytes were usually increased. No regularity was noticed in the variation of eosinophiles or basophiles.

Effect of Wrestling (Table II).—The subjects were varsity wrestlers. Samples of blood were taken during intercollegiate competition. Time of participation varied from 2′10″ to 10′. Matches of two to four minutes produced a lymphocytic reaction. Matches over four minutes produced generally a neutrophilic reaction with exception of cases number 3, 5, and 7.

Effect of Swimming (Table III).—Varsity swimmers were tested. Samples of blood were taken during trials. Shorter distances (60 to 220) gave predominantly a lymphocytic phase, although sometimes it was almost a neutrophilic phase (case No. 5). Distances of 220 to 880 gave markedly neutrophilic phases.

Discussion.—The blood changes indicate that there is a relationship between the amount and intensity of work on one hand and the character of the change on the other. Exercises of short duration usually

produce a definite lymphocytic phase, exercises of a medium duration usually produce a neutrophilic change. Data obtained in wrestling show clearly how the intensity of exercise affects the blood. In cases number 5 and 7 although men were wrestling over five and six minutes respectively, nevertheless lymphocytic phases were produced. These men wrestled in a rather uninteresting defensive way, without any great expenditure of energy.

POSSIBLE REASONS FOR THE CHANGE IN THE BLOOD MORPHOLOGY

Although all investigators agree that the number of white blood corpuscles in the peripheral blood increases, nevertheless they differ in the interpretation of this fact. Is this increase due to a redistribution of the corpuscles or due to a production of the new ones? Egoroff (1924) believes that the myogenic leucocytosis is the result of formation of the new cells by the red bone marrow, suggesting that the waste products of the blood act as stimulants. Kuznetzoff (1928) found that injection of lactic acid in blood brought about changes similar to those obtained after muscular exercises. Herxheimer (1924), Ernst and Herxheimer (1924) share the views of Egoroff, and point to the fact that after the training period, myogenic changes in the blood are less noticeable than before training, whereas if they were due to the mechanical factors only, there should be no difference. Jokl (1931) states that new cells could not be produced in such a short time as fifty seconds or less, yet the changes in the blood after exercise taking this time are considerable. Ponder, Saslow, and Schweizen (1931) explain these changes as a result of redistribution of the blood. Schneider and Havens (1915) considered these changes as the relative ones and suggested that the action of adrenal glands may be taken as one of the factors in this change. They experimented on one person, and obtained changes half an hour after the administration of adrenalin. Recently Hartman and Jokl (1930) again pointed to the parallelism between the myogenic and adrenalin changes in the organism, but they have not added anything essentially different from the suggestions of Schneider and Havens. Some light may be thrown on this problem by observing the morphological changes in blood resulting after a sufficiently long period of training.

Ernst, Herxheimer (1924), Egoroff (1926) think that training induces lymphocytosis. Thörner (1929) testing the contestants in the Amsterdam Olympic Games, found training in sprinting produces a medium lymphocytosis and a shift to the left. Training for the long distances causes a noticeable lymphocytosis. Later Thörner (1932) found that training of dogs results in a slight increase in lymphocytes with a shift to the left. Hawkins (1932) testing the blood of varsity swimmers came to the conclusion that an increase in the neutrophiles

was running parallel with training, dropping during a period of vacation and increasing again afterwards.

From the above the only conclusion that can be drawn is that the changes in the blood after muscular exercise are mostly mechanical. An increased circulation washes out some of the cells. The constriction of the blood vessels in the abdominal cavity caused by the presence of the waste matter in the blood and by excitation of the vasoconstrictors results in sending of the blood elements into the active areas. The fact that during prolonged exercises the percentile relation of all forms of the corpuscles becomes the same as during a period of rest, although the absolute number increases, seems to support the mechanistic theory. A long enough period of exercise allows a more uniform extraction of all kinds of corpuscles from the storage places. It is possible to visualize the whole cycle in this way: during a very brief exercise the per cent of leucocytes increases more noticeably because they are more easily sent into the blood from the lymph nodes. Then the neutrophiles are taken from the storage places. This happens after a lymphocytic phase even if the exercises are *discontinued*. In addition to this it is possible to assume that the process of the blood formation is somewhat accelerated and therefore even the younger forms are released in greater quantity. The main stimulant for these blood changes is probably the waste matter in the blood, although the nervous regulation undoubtedly plays an important part. Lewitina and co-workers (1932) showed that even mental work, which does not produce any appreciable increase in the amount of waste products in the blood, produced morphological changes in blood similar to those obtained during muscular work.

SUMMARY

The effect of basketball, wrestling, and swimming on the differtial count of the white blood corpuscles was studied in thirty athletes.

1. A basketball game of eight to twenty minutes produces a neutrophilic reaction. Monocytes are usually increased. No regularity is noticed in the reaction of the eosinophiles or basophiles.

2. Short periods of wrestling produce a lymphocytic phase, long periods result in a neutrophilic phase. Effect of intensity of exercise is noted, since in the three cases of slow wrestling over four minutes duration, still no neutrophilic reaction develops.

3. Swimming from 60 to 220 yards produces a lymphocytic phase with a tendency to neutrophily. Longer distances give a markedly neutrophilic reaction with a shift to the left.

4. The increase in the number of the white blood corpuscles is largely due to a redistribution of the blood and release of the corpuscles from the "storage places." Exercises also probably stimulate the release of the younger forms by the red bone marrow.

5. Training causes either lymphocytosis or leucocytosis, depending on the type of exercise.

I wish to thank the experimental subjects for their kindness; and Coaches T. K. Cureton, Jr., E. J. Hickox, E. A. Pennock, and J. L. Rothacher for their cooperation.

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TABLE I

CHANGES IN BLOOD AFTER BASKETBALL

Subject	Minutes of participation	Neutrophiles Young %	Neutrophiles Segmented %	Monocytes %	Eosinophiles %	Basophiles %	Lymphocytes %
1	8	*b* 2.0	65	3.5	.5	..	29.0
		a 3.0	67	5.0	1.0	..	24.0
2	9	*b* 1.0	77	4.0	3.0	..	15.0
		a 3.0	74	5.0	1.0	..	17.0
3	10	*b* 0.0	65	4.0	1.0	.5	29.5
		a 3.0	67	5.0	1.0	..	24.0
4	10	*b* 1.5	73	4.5	.5	.5	20.0
		a 3.0	73	5.0	1.0	..	18.0
5	15	*b* 1.5	68	2.0	.5	..	28.0
		a 4.0	70	3.0	.5	.5	22.0
6	15	*b* 3.0	65	4.0	1.0	..	27.0
		a 5.0	67	5.0	1.0	.5	21.5
7	17	*b* 2.0	73	2.0	...	..	23.0
		a 2.0	75	4.0	1.0	..	18.0
8	18	*b* 2.0	70	3.0	1.0	.5	23.5
		a 6.0	71	4.0	...	..	19.0
9	18	*b* 4.0	68	3.0	2.0	.5	22.5
		a 5.0	70	5.0	1.0	..	19.0
10	20	*b* 3.0	65	3.0	1.0	.5	27.5
		a 6.0	68	4.0	2.0	..	20.0

NOTE.—*a*. After the exercise.
b. Before the exercise.

TABLE II

CHANGES IN THE BLOOD AFTER WRESTLING

Subject	Minutes of participation	Neutrophiles Young %	Neutrophiles Segment. %	Monocytes %	Eosinophiles %	Basophiles %	Lymphocytes %
1	2.10	*b* 1.5	68.0	5.0	2.0	..	23.5
		a 2.5	57.5	6.5	2.0	..	31.5
2	2.30	*b* 4.0	66.0	4.5	1.5	..	24.0
		a 6.0	56.0	4.0	0.0	..	34.0
3	4.10	*b* 1.5	48.0	7.0	3.0	.5	40.0
		a 4.5	42.0	6.0	2.5	..	45.0
4	4.32	*b* 4.0	51.0	2.5	1.5	.5	40.5
		a 7.0	49.0	6.5	.5	..	37.0
5	5.10	*b* 7.0	65.0	6.0	1.5	.5	20.0
		a 10.5	53.0	6.0	2.0	..	28.5
6	5.15	*b* 1.5	49.5	6.5	1.0	..	41.5
		a 2.0	62.5	4.0	1.0	.5	30.0
7	6.5	*b* 5.0	51.5	5.0	3.0	.5	35.0
		a 4.0	49.0	5.0	2.0	..	40.0
8	7.10	*b* 4.0	57.5	5.5	4.0	..	29.0
		a 8.0	54.5	8.0	0.5	..	29.0
9	9	*b* 5.0	50.0	5.5	2.0	..	37.0
		a 6.5	66.0	5.0	1.5	..	21.0
10	9	*b* 4.0	59.0	3.5	3.0	.5	30.0
		a 5.0	60.0	5.0	2.0	..	28.0

NOTE.—*a*. After the exercise.
b. Before the exercise.

TABLE III

CHANGES IN BLOOD AFTER SWIMMING

Subject	Type of activity		Neutrophiles Young %	Neutrophiles Segmented %	Monocytes %	Eosinophiles %	Basophiles %	Lymphocytes %
1	60 yds	*b*	1.5	67.0	5.0	1.5	0.0	25.0
		a	2.0	55.0	5.0	1.5	0.0	36.5
2	60 "	*b*	4.0	64.0	3.0	2.0	1.0	26.0
		a	5.0	53.0	2.0	2.0	0.5	37.5
3	100 "	*b*	4.0	63.0	5.0	2.5	0.0	25.5
		a	6.0	45.0	6.5	2.5	0.0	40.0
4	100 "	*b*	1.0	57.0	5.0	3.0	0.0	34.0
		a	2.0	33.0	8.0	1.5	0.5	55.0
5	220 "	*b*	.5	75.0	2.5	0.5	0.0	21.5
		a	2.0	74.0	1.0	.5	0.0	22.5
6	220 "	*b*	5.0	56.0	4.0	2.0	0.0	33.0
		a	2.0	58.5	2.0	2.0	0.0	35.5
7	440 "	*b*	0.0	64.0	3.0	3.0	1.0	29.0
		a	6.0	62.0	1.0	1.0	0.0	30.0
8	440 "	*b*	2.0	70.0	4.0	0.0	0.5	23.5
		a	6.0	67.0	5.0	1.0	0.5	20.5
9	880 "	*b*	7.0	48.5	10.0	2.0	0.5	32.0
		a	7.0	65.5	5.0	1.0	0.0	21.5
10	880 "	*b*	2.0	60.0	1.0	2.0	0.0	35.0
		a	7.0	70.0	.5	1.0	0.0	21.5

NOTE.—*a*. After the exercise.
b. Before the exercise.

Analysis of the Propelling Force in the Crawl Stroke

By Peter V. Karpovich, M.P.E., M.D.

IN COACHING swimming it is of great importance to detect and correct the errors in the performance as soon as possible. Much of this detection is an art and depends on the subjective qualities of the coach. A proper arm action, a degree of flexion in the joints, an amount of body rotation, cannot be accurately measured while a man is swimming; however, a deviation from the correct way can be noticed by an experienced coach. This will probably continue forever, bringing quite satisfactory results, nevertheless any method which can be used for an objective analysis of performance will be of great help. A good deal of speculation was aroused by a relative value of the arms and legs in the crawl stroke.

The purpose of the present study is to find the relative value of the arm and leg action in the crawl stroke and show how this can be utilized in practical coaching of swimming.

METHOD USED

Principle.—The speed which swimmers were able to develop using arms alone, legs alone, and arms and legs together was found. The corresponding propelling force was then calculated from the resistance formulae (Karpovich, 1933). The relation between the forces was found.

Procedure.—In testing swimmers, a procedure analogous to that described by Cureton (1930) was used. The subjects were asked to swim with the maximum speed, one length of the pool three times, using first arms alone, next legs alone, and finally the whole stroke. After each test they rested for a few minutes (not less than three). When the arms alone were used, the feet were supported by a water-polo ball tied between the ankles by means of a special strap.* When the legs alone were used, the same ball was held in the hands, the arms being extended forward. The ball was slightly deflated—just enough to support seven pounds of weight. A dead start was used throughout. In order to eliminate errors due to reaction time, the start was given in the following manner: "Get ready, one, two, go." The time intervals between "one," "two," and "go" were equal. The starter always held the swimmer by the ankles, releasing him on "go." The subjects were instructed to breathe as little as possible if at all during swimming.

* This strap was kindly supplied by the A. G. Spalding & Bros. Company.

RELATION BETWEEN THE PROPELLING FORCE AND RESISTANCE

From elementary mechanics we know that $ma = F$, where m is mass, a, acceleration, and F, the acting force. If the moving object has to overcome resistance R, then $ma = F\text{-}R$. In the case of a constant speed, acceleration is equal to zero and the formula becomes: $mo = F\text{-}R$ or $o = F\text{-}R$, or $F = R$. In other words: *when speed is constant, the propelling force is equal to the water resistance.*

This can be applied to crawl swimming although the speed is not constant. The proof of this is as follows: in crawl we recognize acceleration and deceleration phases. The first phase takes place during the arm pull, and the second betweeen the arm pulls. It has been graphically shown (Karpovich 1930) that in swimming with the same average speed, acceleration is equal to deceleration, which of course should be expected. (See diagram No. 1.) If acceleration were greater,

DIAGRAM 1.—Showing the variation of speed in the fast crawl stroke. Speed was obtained by means of the Natograph. In this experiment, speed varied between four and five ft./sec. (approximately). The upstrokes of the curve correspond to acceleration and downstrokes to deceleration phases. It can be noted that acceleration and deceleration are equal.

then it would have been a case of an ever increasing speed; and if the contrary were true, it would have been a case of constantly slowing speed. Let a be acceleration and $-a'$ deceleration. Then we have: $ma = F - R$, acceleration phase; $-ma' = F' - R'$, deceleration phase. Adding both equations we obtain: $ma - ma' = F - R + F' - R'$; but since it was shown that $a = a'$, then $ma - ma' = o$, therefore $F - R + F' - R' = o$ or $F + F' = R + R'$, which means that *propelling force in the crawl stroke is equal to water resistance.*†

SPEED RELATION IN THE CRAWL AND BACK STROKES

Suppose that T_a is the time of swimming 60 feet using arms alone,
T_l is the time of swimming 60 feet using legs alone,
T_w is the time of swimming 60 feet using whole stroke.
Since speed is measured by dividing time into the distance, we have the corresponding speeds:

$$V_a = \frac{60}{T_a},\ V_l = \frac{60}{T_l} \text{ and } V_w = \frac{60}{T_w}.$$

† It should be borne in mind that we are dealing with the propelling force only, and not the muscular force used in general, because some of it is spent on maintaining the body on the surface of the water.

We have seen that the resistance and propelling force in the crawl stroke are equal; therefore, it is possible to use a resistance formula originated by the present writer (1933) for calculation of the force.

The general form of resistance formula is $R = k \quad V^n$, where R is water resistance, k a constant varying from .5 to .8 depending on the size of the individual, V is the speed and n an exponent varying from 2 to 2.07.

Since propelling force is equal to water resistance, we can write: $F = k \quad V^n$. The forces developed in attaining the speeds V_a, V_l, and V_w will be: $F_a = k\ V_a{}^n$, $F_l = k\ V_l{}^n$, $F_w = k\ V_w{}^n$.

In an ideal case without any loss of power we have:

1. $F_a + F_l = F_w$, or $k\ V_a{}^n + k\ V_l{}^n = k\ V_w{}^n$.

Dividing both sides of equation by k we obtain:

2. $V_a{}^n + V_l{}^n = V_w{}^n$.

If we accept the square as a sufficient exponent, then we obtain a very simple law of squares:

3. $V_a{}^2 + V_l{}^2 = V_w{}^2$.

The square of the speed of the whole stroke is equal to the sum of squares of speeds developed with the arms and legs separately. This can be represented graphically. (Fig. 2.)

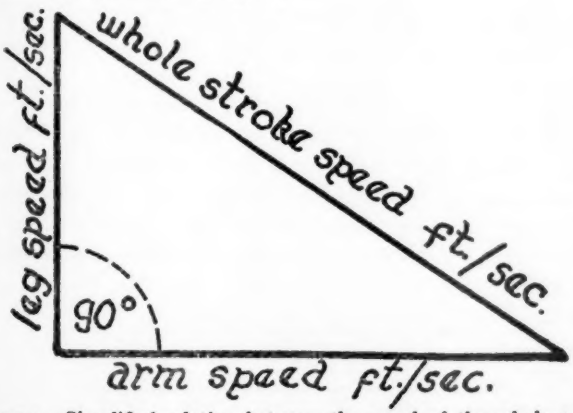

DIAGRAM 2.—Simplified relation between the speed of the whole crawl stroke and the speeds developed with the arms and legs separately. (Speed of the whole stroke)^2 = (speed of the arms)^2 + (speed of the legs)^2.

EXPERIMENTAL VERIFICATION OF THE DEDUCED LAWS

Some Springfield College swimmers were tested and the following formulae were applied: $V_w{}^2 = V_a{}^2 + V_l{}^2$ and $.65V_w{}^{2.05} = .65V_a{}^{2.05} + .65V_l{}^{2.05}$. The second formula is simply $F_w = F_a + F_l$, adapted to the experimental cases, since the majority of the boys were of a large type.

The results are given in Table I. It may be noticed that these formulae give a surprisingly close prediction for fairly good swimmers.

The average difference between the calculated and predicted time was .11 seconds for the first formula and .04 for the second. Using data collected by Wilson, it was found that prediction with the first formula differed from the actual average by .24 seconds and with the second formula by .08 seconds. *This shows that the laws of squares and summation of forces are correct.*

CONTRIBUTION BY THE LEGS AND ARMS

Fifty-five swimmers were divided into 5 groups according to the time of swimming 60 feet, using the whole crawl stroke. The force developed was calculated by means of a formula: Force $= .65V^{2.05}$. The results are represented below. (Table II.)

TABLE I

VERIFICATION OF THE SPEED LAWS

Time in seconds.*							
	Actual			Calculated		Difference	
	Arms	Legs	Whole	V^2	$V^{2.05}$	V^2	$V^{2.05}$
Scho.	13.2	16.2	10.6	10.2	10.3	.4	.3
	14.1	16.6	10.9	10.7	10.8	.2	.1
San.	12.4	20.0	10.2	10.5	10.6	—.3	—.4
	12.8	20.6	10.4	10.9	11.0	—.5	—.6
For.	11.2	18.2	9.8	9.5	9.7	.3	.1
	12.4	18.6	10.0	10.3	10.4	—.3	—.4
Urq.	12.8	26.2	11.7	11.5	11.6	.2	.1
	12.6	29.0	11.8	11.6	11.6	.2	.2
Lan.	13.8	18.2	11.9	11.0	11.0	.9	.9
Par.	11.4	18.6	10.1	9.7	9.6	.4	.5
	12.2	18.2	11.6	10.1	10.2	—.5	—.6
	11.8	18.3	10.2	10.0	10.0	.2	.2
Mor.	15.4	21.4	12.6	12.5	12.6	.1	0
Fow.	13.0	17.0	10.6	10.3	10.5	.3	.1
MacM.	13.0	22.5	11.3	11.3	11.3	0	0
Coyk.	14.0	19.6	11.6	11.4	11.5	.2	.1
Average			10.9	10.7	10.8	.11	.04

* Swimming distance 60 feet.

TABLE II

CONTRIBUTION TO THE PROPELLING FORCE BY THE ARMS AND LEGS

Time for swimming 60 ft., whole stroke	Number of cases	Average Force in lbs. Arms	Legs	Whole stroke	Ratio Arms / Legs	Per cent Arms	Legs
1 10—11	15	16.89	7.31	24.20	2.31 / 1	69.8	30.2
2 11—12	13	14.53	5.56	20.09	2.61 / 1	72.3	27.7
3 12—13	14	12.59	4.42	17.01	2.85 / 1	74.0	26.0
4 13—14	6	10.96	3.55	14.51	3.09 / 1	75.6	24.4
5 15—21	7	6.19	1.85	8.04	3.35 / 1	77.0	23.0

Table II shows that better swimmers have a better arm and leg action. It also shows that the ratio and percentage may be misleading. A greater percentage of arm contribution in poor swimmers may be interpreted as due to a greater arm power, whereas it is merely due to a poorer leg action.

SQUARES OF THE SPEEDS RELATE TO EACH OTHER AS THE CORRESPONDING FORCES

V_a, V_l, and V_w are the speeds for the arms, legs, and whole stroke and F_a, F_l, and F_w are the corresponding forces. Then $F_a = .65V_a^{2.05}$, $F_l = .65V_l^{2.05}$ and $F_w = .65V_w^{2.05}$. Dividing force of the arms by the force of the legs we obtain the arm-leg ratio

$$\frac{.65V_a^{2.05}}{.65V_l^{2.05}} = \frac{V_a^{2.05}}{V_l^{2.05}}.$$

The per cent contribution of the arms will be:

$\frac{F_a}{F_w} \times 100$, or $\frac{.65V_a^{2.05}}{.65V_w^{2.05}} \times 100$, or $\frac{V_a^{2.05}}{V_w^{2.05}} \times 100$. In every case the coefficient was cancelled in the final formula, which means that the calculation of the relative arm and leg value is independent of the coefficient.

The whole procedure may be simplified in this way: *In order to find the arm-leg ratio contribution to the propelling force in a crawl stroke, divide the square of the arm speed by the square of the leg speed. To find the per cent contribution by the arms (or legs) divide the square of the arm (or leg) speed by the square of the speed of the whole stroke and multiply by one hundred.*

THE LENGTH OF THE SWIMMER'S BODY HAS NO EFFECT UPON THE VALIDITY OF THE TEST

When a man swims supposedly 60 feet, he actually swims less, the difference being the length of his body with extended arms and legs. This difference may be as great as 9 feet. Suppose that h is the body length with extended arms and legs, then the actual distance covered during a 60-foot swim will then be $60 - h$. Let T_a, T_l, and T_w represent the time of swimming with arms, legs, and whole stroke respectively. Then the corresponding speed will be $\frac{60-h}{T_a}$, $\frac{60-h}{T_l}$, and $\frac{60-h}{T_w}$. Using the law of squares of speeds we have $\frac{(60-h)^2}{T_a^2} + \frac{(60-h)^2}{T_l^2} = \frac{(60-h)^2}{T_w^2}$. Dividing both sides of this equation by

$(60 - h)^2$, we have $\frac{1}{T_a^2} + \frac{1}{T_l^2} = \frac{1}{T_w^2}$ which shows that the equation is not affected by the length of the body.

THE LOSS OF KINETIC ENERGY AT THE END OF THE POOL DOES NOT AFFECT THE VALIDITY OF THE PRESENT CALCULATIONS

Suppose that m is the mass of the swimmer's body, V_w the speed of the whole stroke, V_a the speed with the arms alone, and V_l the speed with legs alone. The corresponding kinetic energies will be $\frac{mV_a^2}{2}$, $\frac{mV_l^2}{2}$, and $\frac{mV_w^2}{2}$. The sum of the losses during the arm and leg tests will be: $\frac{mV_a^2}{2} + \frac{mV_l^2}{2} = \frac{mV_a^2 + mV_l^2}{2}$ but $V_a^2 + V_l^2 = V_w^2$, therefore $\frac{mV_a^2}{2} + \frac{mV_l^2}{2} = \frac{mV_w^2}{2}$.

The sum loss of kinetic energy during arm and leg tests is equal to the loss during the whole stroke, and therefore does not affect our calculations.

THE USE OF THE BALL IN THE TESTS HAS NO EFFECT ON THE VALIDITY OF THE PRESENT CALCULATIONS

From the experimental data it is obvious that the ball used (a slightly deflated water-polo ball, with a circumference reduced to 23½ inches) adds just enough resistance to equal any natural loss of power when arms and legs are working together. If an extremely large or small ball is used, results will not be reliable. With a small ball the legs will sink and increase resistance, while in the other case the resistance caused by the ball itself may be high.

INTERPRETATION OF THE RESULTS OBTAINED DURING THE TEST

The time of swimming sixty feet with arms alone or legs alone in itself is very significant. The person can see immediately how efficiently his arms or legs are working and can concentrate his attention on the weaker limbs. By merely comparing his figures with those in Table III he can see to which class of swimmers he belongs, also what he has to improve and why.

Applying the law of squares of speeds, he can find how fast he should swim sixty feet, using his arms and legs together. This is a rather tedious procedure requiring squaring and then extraction of a square root, but with the aid of Table IV, this can be done automatically in about twenty-five seconds. If the predicted time is a great deal

faster than the actual, repeat the test. If this is persistent, the man has imperfect coordination which may be improved by practice. If the predicted time is *slower* than the actual, repeat the test. Warn the man to reduce the number of respirations while swimming, since the propelling force is lessened during respiratory movement of the chest. Very often this is the cause of the discrepancy. (See Table I, Subjects San., For., and Par.) If reducing the number of respirations does not change the relation, then it probably means that the man cannot use his *legs alone* efficiently. If he is a champion swimmer there is no reason to worry, test or no test, but if he is not a fast swimmer, his legs should be exercised. There is one more aspect of this test. It vividly demon-

TABLE III

SHOWING THE AVERAGE RELATION BETWEEN THE EFFECTIVENESS OF THE ARMS AND LEGS, AND THE WHOLE STROKE

	Time of swimming sixty feet with maximum speed in seconds		
	Whole Stroke	Arms Alone	Legs Alone
1	9—10	11.3	17.6
2	10—11	12.2	18.4
3	11—12	13.2	21.2
4	12—13	14.1	23.6
5	13—14	15.1	26.2
6	14—15	16.4	30.8
7	15—21	20.0	32.4

strates the importance of the legs as well as the arms, and beginners will endeavor to secure the maximum power from both.

This test gives better results with a sixty-foot distance or less. With a seventy-five-foot distance, breathing becomes too frequent, and it is also more difficult to remain in the same lane.

PRACTICAL SUGGESTIONS

1. In giving the test, use a dead start and commands suggested in this article; "Get ready, one, two, go." The time intervals between one, two, and go should be equal. This will minimize errors due to interference of the reaction time.

2. Compare the time for the legs and arms with Table III. Inform the subject if his arms or legs are found to be inefficient, and prescribe the necessary exercises.

3. Use the author's prediction Table IV and calculate the speed for the whole stroke. Compare this with the actual time.

a) If time is the same or the difference is less than .3, the man's coordination is good.

TABLE IV

TABLE OF SQUARES OF SPEED FOR SIXTY-FOOT SWIM

T = time; V^2 = square of speed.

T	V^2	T	V^2	T	V^2	T	V^2	T	V^2	T	V^2
9.0	44.36	14.0	18.40	19.0	9.99	24.0	6.25	29.0	4.28	37.0	2.63
.1	43.56	.1	18.15	.1	9.86	.1	6.20	.1	4.25	.5	2.56
.2	42.51	.2	17.89	.2	9.73	.2	6.15	.2	4.22	38.0	2.50
.3	41.60	.3	17.64	.3	9.61	.3	6.10	.3	4.20	.5	2.43
.4	40.70	.4	17.39	.4	9.55	.4	6.05	.4	4.18	39.0	2.37
.5	39.82	.5	17.14	.5	9.43	.5	6.00	.5	4.15	.5	2.31
.6	38.94	.6	16.89	.6	9.36	.6	5.95	.6	4.11	40.0	2.25
.7	38.32	.7	16.65	.7	9.24	.7	5.91	.7	4.08	.5	2.20
.8	37.45	.8	16.40	.8	9.18	.8	5.86	.8	4.05	41.0	2.14
.9	36.72	.9	16.24	.9	9.06	.9	5.81	.9	4.02	.5	2.09
10.0	36.00	15.0	16.00	20.0	9.00	25.0	5.76	30.0	4.00	42.0	2.05
.1	35.28	.1	15.76	.1	8.94	.1	5.71	.1	3.97		
.2	34.57	.2	15.60	.2	8.82	.2	5.66	.2	3.95		
.3	33.99	.3	15.37	.3	8.76	.3	5.62	.3	3.92		
.4	33.29	.4	15.21	.4	8.64	.4	5.57	.4	3.90		
.5	32.60	.5	14.98	.5	8.59	.5	5.52	.5	3.87		
.6	32.04	.6	14.82	.6	8.47	.6	5.48	.6	3.85		
.7	31.48	.7	14.59	.7	8.41	.7	5.43	.7	3.82		
.8	30.91	.8	14.44	.8	8.29	.8	5.38	.8	3.80		
.9	30.25	.9	14.21	.9	8.24	.9	5.34	.9	3.77		
11.0	29.81	16.0	14.06	21.0	8.18	26.0	5.32	31.0	3.75		
.1	29.27	.1	13.84	.1	8.07	.1	5.28	.2	3.70		
.2	28.73	.2	13.69	.2	8.01	.2	5.24	.4	3.65		
.3	28.20	.3	13.54	.3	7.95	.3	5.20	.6	3.61		
.4	27.67	.4	13.32	.4	7.84	.4	5.16	.8	3.56		
.5	27.14	.5	13.25	.5	7.78	.5	5.13	32.0	3.52		
.6	26.73	.6	13.03	.6	7.73	.6	5.09	.2	3.47		
.7	26.32	.7	12.89	.7	7.67	.7	5.05	.4	3.43		
.8	25.50	.8	12.82	.8	7.56	.8	5.01	.6	3.39		
.9	25.40	.9	12.60	.9	7.51	.9	4.98	.8	3.35		
12.0	25.00	17.0	12.46	22.0	7.45	27.0	4.94	33.0	3.31		
.1	24.60	.1	12.32	.1	7.40	.1	4.90	.2	3.27		
.2	24.21	.2	12.18	.2	7.34	.2	4.87	.4	3.22		
.3	23.81	.3	12.04	.3	7.29	.3	4.83	.6	3.19		
.4	23.33	.4	11.90	.4	7.18	.4	4.80	.8	3.15		
.5	23.04	.5	11.77	.5	7.13	.5	4.76	34.0	3.11		
.6	22.66	.6	11.63	.6	7.08	.6	4.73	.2	3.08		
.7	22.28	.7	11.49	.7	6.97	.7	4.69	.4	3.04		
.8	22.00	.8	11.36	.8	6.92	.8	4.66	.6	3.01		
.9	21.62	.9	11.22	.9	6.86	.9	4.63	.8	2.97		
13.0	21.34	18.0	11.09	23.0	6.81	28.0	4.59	35.0	2.94		
.1	20.98	.1	10.96	.1	6.76	.1	4.56	.2	2.91		
.2	20.70	.2	10.82	.2	6.71	.2	4.53	.4	2.87		
.3	20.34	.3	10.69	.3	6.66	.3	4.50	.6	2.84		
.4	20.07	.4	10.63	.4	6.55	.4	4.46	.8	2.81		
.5	19.71	.5	10.50	.5	6.50	.5	4.43	36.0	2.78		
.6	19.45	.6	10.37	.6	6.45	.6	4.40	.2	2.75		
.7	19.18	.7	10.24	.7	6.40	.7	4.37	.4	2.72		
.8	18.92	.8	10.18	.8	6.35	.8	4.34	.6	2.69		
.9	18.66	.9	10.05	.9	6.30	.9	4.31	.8	2.66		
14.0	18.40	19.0	9.99	24.0	6.25	29.0	4.28	37.0	2.63		

The use of Table IV. Let 12.2 sec. and 20.3 represent the time for the arms alone and legs alone. The corresponding squares of speed will be found in the columns marked V^2. For 12.2 it is 24.21 and for 20.3 it is 8.76. To predict the speed for the whole stroke, add the found squares. The sum is 32.97. Read back into column V^2 and find a number nearest to 32.97. It will be 33.29. The corresponding time in column T will be 10.4. This is the predicted time for the whole stroke.

b) If the predicted time differs from the actual by more than .3, repeat the test, eliminating excessive breathing, especially during the leg test. If the difference still persists then:

(1) An actual time slower than the predicted means an imperfect coordination.

(2) If the actual time is faster than the predicted, this shows that the man cannot use his arms or legs alone (usually legs) as efficiently as when he is using them together. This paradox may possibly be explained since a separate use of the legs is a rather unusual procedure for a swimmer.

4. Use a sixty-foot distance. It is more reliable than seventy-five.

5. Use a ball of approximately twenty-three and one-half inches in circumference, such as a slightly deflated water-polo ball. A great deal smaller or larger ball will not give reliable results.

SUMMARY

1. The effectiveness of the arms and legs in the crawl stroke was studied.

2. It was shown that in swimming with a uniform speed, propelling force is equal to water resistance.

3. It was shown that propelling force of the whole stroke is equal to the sum of the propelling forces developed by the arms and legs separately (maximum action in each case).

4. Speed of the whole stroke raised to a 2.05 degree is equal to the sum of the arm and leg speed, each in 2.05 degree. $V_w^{2.05} = V_a^{2.05} + V_l^{2.05}$. Difference between the actual and calculated time being only .0375 to .08 seconds.

5. The above can be simplified as follows: The square of the speed of the whole stroke is equal to the sum of the squares of the arm and leg speeds. $V_w^2 = V_a^2 + V_l^2$. This can be illustrated by a right triangle, the sides of which are equal to the arm and leg speed; then the hypotenuse will be equal to the speed of the whole stroke.

6. Contribution of the arms and legs was found. Good crawl swimmers derive about 70 per cent from their arms and 30 per cent from their legs, ratio 2.3/1. Poor swimmers derive 77 per cent from the arms and only 23 per cent from their legs, ratio being 3.35:1.

7. Formula $V_w^2 = V_a^2 + V_l^2$ was suggested as an aid in coaching, and application was explained.

8. A special table for prediction of speed was prepared.

9. It was shown that the body length does not affect the test.

10. It was shown that the loss of kinetic energy due to a sudden stop at the edge of the pool does not affect the test.

11. The sixty-foot distance is better for this test than a seventy-five-foot distance.

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Effect of Training in Swimming Upon the Morphological Composition of the Blood*

By CHARLES C. HAWKINS, B.S., M.P.E.
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THE PURPOSE of this study was to investigate the changes occuring in the differential count of the white blood corpuscles during training in swimming.

Procedure.—Eight men selected from the varsity swimming squad were tested before, during, and after the swimming season, the blood being taken as often as every other day. In addition, samples of the blood were taken before and after week-ends and vacation. Blood was taken either from finger tip or lobe of the ear. The absolute as well as the differential counts were found.

Summary.—

1. At the beginning of training there is an immediate rise in the younger forms of the neutrophiles, which reaches it maximum at the peak of the training and returns to normal soon after discontinuation of training.

2. Training in swimming not only causes a redistribution of the white blood corpuscles, but also increases the activity of the blood forming tissues.

*Abstract from Master's thesis, 1932.

The Effect of Modifications in Respiration on Speed of Recovery from Fatigue*

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THE PURPOSE of this study was to find out whether modifications in respiration would have any effect on the speed of recovery from fatigue. Three types of respiration were used: (1) natural breathing, (2) breathing with emphasis on expiration, and (3) breathing with emphasis on inspiration.

Method.—The resting pulse and respiration rate were found. Then the subjects exercised and the time necessary for the pulse and respiration to come to normal was noted. The exercise consisted either in running in place for two minutes, or climbing and descending several flights of stairs. Sixty-four subjects were tested after the first kind of exercise, and sixty-eight after the second. Each test was repeated three times, using different types of respiration during recovery. In addition to these experiments metabolism tests were given to the three subjects (three times to each person) in order to find the effect of the different types of respiration on the return of metabolism to normal, after stair-climbing.

The results of the study may be summarized as follows:

1. One hundred and thirty observations showed that the fastest recovery of the pulse and respiration rates was after breathing with *emphasis on inspiration.*

2. Natural breathing, and breathing with emphasis on expiration have the same effect on recovery of the pulse rate. Respiratory rate becomes normal sooner after breathing with emphasis on expiration than after natural breathing.

3. The metabolism studies also showed that emphasis on inspiration is more beneficial than the other two types of respiration used.

* Abstract from Master's Thesis, 1932.

Study of Breath-Holding*

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THE PURPOSE of this study was to determine what physiological and other factors are related to breath-holding.

Method I.—A group of ten college students was selected. They practiced breath-holding after inspiration and expiration at least fifteen times a day for four weeks. Twice a week their breath-holding ability was tested and also samples of the alveolar air before and after breath-holding were analyzed for the oxygen and carbon dioxide content.

Method II.—One hundred and thirty-one students of Springfield College were tested for their vital capacity, and their breath-holding time was found after three inspirations, after one inspiration, and after a forced expiration.

Summary.—

1. The break, or inability to hold the breath any longer, is due to the attainment of a certain carbon dioxide percentage in the alveolar air rather than a deficiency of oxygen.
2. Breath-holding is related to: physical condition, emotional strain, ability to withstand the accompanying discomfort, and will power or determination.
3. Improvement can be made with practice.
4. Variations of breath-holding time and alveolar composition are due to factors stated in (2) above.
5. It is impossible to state specifically, in this study, why the oxygen percentage drops below that of the carbon dioxide which remains the same after breath-holding in many cases.
6. There is very little, if any, relationship between breath-holding and vital capacity.
7. It seems impossible to hold the breath under normal conditions until a state of unconsciousness is reached.
8. The problem aside from being a physiological one is concerned with psychological factors.

* Abstract from Master's Thesis, 1932.

An Abstract from the Thesis "A Study Of Athletic Condition in Relation to Circulation and Weight"

By J. L. Rothacher, B.P.E., M.P.E.

THIS research study was to determine the effect of exercise on the circulation and weight of athletes and non-athletes.

The individuals who were tested were members of varsity football, basketball, track and swimming teams and students who were not active in any form of athletic competition.

The investigation was to attempt to answer the following questions: In what condition do you find the heart rate and blood pressure of the athlete following exercise (varsity practice) as compared with the normal? How does the athlete compare with the non-athlete when given the Schneider Efficiency Test? What effect does exercise have on weight?

Approximately eighty men were examined during the period of the college year, forty athletes (football, basketball, swimming, and track) and forty non-athletes, using as a basis the Schneider Efficiency Test. "This is the study of: (1) normal heart rate during reclining; (2) normal heart rate during standing; (3) the difference between the normal heart rate reclining and standing; (4) the increase of heart rate following exercise (consisting of knee raising 20 times in 5 seconds); (5) the time the pulse takes to return to normal (0–60 sec., 61–90, 91–120 sec, 121 sec. plus); (6) the difference between the blood pressure reclining and standing.

"In addition to the above examinations, the athlete in the fall had his systolic pressure taken in the reclining and standing position a second time during the same day, making a total of eight parts in each of the athlete's examination. This followed his work on the varsity squad.

"All the men were examined under the same conditions and in the same way. Each man was examined at least once each week. The subjects were permitted to rest in the sitting position for 20 – 50 minutes during a football lecture after which they assumed the reclining position for three minutes before they were tested. While in the reclining position the pulse rate was taken and counted for twenty seconds, then followed the reclining systolic pressure. The men then stood in relaxed position for 1 or 2 minutes before the heart rate was again taken for 20 seconds. The systolic pressure was also recorded in this position. The subject was then required to take 20 knee-raising exercises in 5 seconds.

Immediately upon the completion of this exercise, the heart rate was determined for 20 seconds, again from 61 – 90 seconds, and continued when necessary until the individual had returned to normal. In the winter and spring seasons, however, the heart action was followed for 2½ minutes in every case; that is, the pulse rate was taken immediately following the exercise, then at 61 – 90 seconds, again at 91 – 120 seconds, and at 121 plus seconds. The pulse in each case was counted from the beginning of the period for 20 seconds. This gave 4 different tests of the heart in its recovery. For the athlete, in addition to the above test, a systolic blood pressure test reclining and standing was taken following his varsity work. During the fall 45 minutes to an hour elapsed (after showers) before these tests were given, while during the winter and spring they were taken as soon as possible (before showers) following varsity practice.

"After all the tests were taken, they were averaged first, according to the individual, and second according to the type of activity, e.g., football, either athlete or non-athlete. Charts were made showing the extremes, the median, and mode, and the common or 80 per cent range of each group in each test for all three seasons. Tables of comparison between athletes and non-athletes, between the different sports, etc., were computed. According to the Schneider Test for Efficiency, each man was graded from the results of his tests and by comparing these scores with the perfect score of eighteen and the physically deficient score of nine, a good idea of the condition of the subject could be gained.

"The weights of all men were taken at definite intervals, the day of their regular tests, before and after varsity practice, and comparisons were made to determine the athletic condition in relation to weight."

From the tabulation of the study made in the fall we find the following apparent differences: the heart rate lying is lower in the athlete (64.6) than in the non-athlete (68.3). On standing, the heart rate in the athlete rises to a less degree (76) than does that of the non-athlete (80.2). Comparing the difference between lying and standing, the athlete shows +12 while the non-athlete is +12.3. The heart rate after exercise (20 knee raisings in 5 seconds) is lower in the athlete (97.2) than in the non-athlete (104.). This leads one to conclude that in the athlete any exertion on the part of the subject has less effect on the heart rate than does the same exertion on the part of the non-athlete. The time of recovery to normal heart rate after exercise (20 knee-raisings) was found in both groups, with all men except one, to occur in the first half of the second minute (61–90 seconds). The blood pressure in lying position was almost the same in both groups, athletes 124.3, non-athletes 127.4, but on standing it had a small drop in the case of the athlete (121.9), and remained the same in the case of the non-athlete (127.3). The average difference in the blood pressure lying and standing shows the athlete with 2.6 points decrease while

the non-athlete has but .1 point decrease. These small differences are within the error of observation.

The averages of the 2 extra tests taken of the athletes after exercise (varsity practice), the blood pressure lying and standing, show the blood pressure to be still lower, 114.8 lying and 111.5 standing with an average decrease of 3.2 points. The striking change is the drop below the normal in both the lying (124.3–114.8 or 9.5) and the standing (121.9–111.5 or 10.4).

"A separate heart-rate study of the entire varsity football squad was made during the fall. All the men were required to report for a football lecture following their shower baths. This meeting lasted from twenty to forty minutes. At the beginning of the lecture, the pulse rate of each man was taken, one group in the reclining position, another in the sitting position. This was counted for twenty seconds and recorded. At a given command both groups stood and the pulse rate was again counted for twenty seconds. At the end of the lecture and just before dismissal, a similar test for pulse rate was taken. The men were seated quietly in the interval between the two tests. The reason for such a study was to find out whether a varsity football squad which was forced to rest following a heavy practice received any beneficial results from such an experiment.

"The results show that the pulse rate for both groups (lying and standing, sitting and standing) fell during the rest period; however, the lying and standing group shows a greater decrease of pulse rate than the sitting and standing group. The average difference between the heart rate before and after the lecture in the lying and standing group shows 12.6 and 14.1 respectively while the average difference in the sitting and standing group is but 8.3 and 8.

"These figures seem to indicate that a period of rest in the reclining position, following varsity practice is very much worth while and should be an important part of the conditioning program of the squad."

SUMMARY OF FALL SEASON

1. The heart rate of the athlete is lower than of the non-athlete.

2. The difference in heart rate between the lying and standing positions varies only slightly with the athlete and non-athlete.

3. The heart rate immediately after exercise (twenty knee-raisings) is lower in the athlete than in the non-athlete.

4. In all but one case, the heart rate after exercise returns to normal in the first half of the second minute (sixty-one to ninety seconds).

5. There is a decrease of 2.6 in the blood pressure of the athlete on changing from lying to standing position while the blood pressure of the non-athlete remains the same.

6. The blood pressure of the athletes in changing from lying to standing position after their varsity practice decreases. Both the lying

and standing blood pressure when taken after exercise are below the normal lying and standing blood pressure.

7. One hundred per cent of the athletes show a decrease in blood pressure upon standing after varsity practice.

8. In the study of the heart rate and its return to normal, 100 per cent of both athletes and non-athletes do not return to normal during the first minute after exercise, the first half of the second minute 80 per cent of both groups do not return, but in the last half of the second minute (91–120 seconds) all return to normal.

During the winter season, the examinations were taken under similar conditions to those that prevailed in the fall, with the exception of the tests taken after varsity work, which were conducted in a somewhat different way. In place of allowing the athletes a stated time to rest before examination, an attempt was made to examine them as soon as they finished their varsity work. Members of the varsity basketball, swimming, and track squads, constituted the athletes for this season's tests.

The basketball and track men, however, had some opportunity to adjust themselves due to the lapse of time required in going from the basketball floor or track to the examining room. The conditions of the swimmers were different in that the examiner was their coach and was able to have the men assume the reclining position immediately after drying themselves. This meant that only two or three minutes expired between the finish of their work and the examination, and probably accounts for the higher rates shown. From clinical judgment the sooner the individual is tested following work, the higher the systolic pressure seems to appear.

Averages for athletes in the fall and winter when compared, show very little variation in the parts of the Schneider Test. However, the blood-pressure test in the winter following varsity practice shows a decided increase over the fall tests. One reason for this is the time factor involved. During the fall the men were not examined until they had taken their shower bath and reported to the varsity lecture-room. The winter athletes were examined as soon as possible; the men could not be held for definite periods as they were in the fall. This may account for some differences in the results of the two seasons.

A comparison of the two non-athletic groups, shows the fall non-athlete to be lower in the heart rate lying and standing, lower in the difference between heart rate lying and standing, and lower in the after exercise (twenty knee-raisings in five seconds) test, than the winter non-athlete. However, this same group runs decidedly higher in systolic pressure.

These variations that occur may be the results of the long indoor season, and the number of different activities that the athlete usually indulges in during this season.

During the fall a varsity football man is excused from all other athletic activities; the winter athlete must carry on his regular gymnasium and swimming classes along with his varsity practice. He may in addition elect other forms of physical activities, such as track, wrestling, boxing, fencing, handball, and so forth. Fatigue is probably another factor in these differences. The individual examinations give evidence of this. At the end of the indoor season, a goodly number of men were below their average for the early and midwinter test.

A comparison of the three winter groups of athletes (basketball, swimming, and indoor track) show a decrease in blood pressure upon standing after varsity practice.

The swimmers show a difference of 11.7 while the track and basketball groups drop 15.2. Of the three groups the swimmers and track men show an increase of blood pressure upon rising during the Schneider Test. The difference of heart rate lying and standing shows the swimming to run lower than the other two groups. The test of blood pressure after varsity practice shows the swimmers and basketball men with higher averages than the track athletes. From the results of the test it is difficult to determine which of the three sports is the most strenuous.

SUMMARY

1. Average grades continue to run lower for athletes than for non-athletes.

2. The difference between the heart rate lying and standing is slightly lower for the non-athlete than for the athlete. This varies from the fall result. Fall, athlete 12, non-athlete 12.3; winter, athlete 16.5, non-athlete 16.4.

3. The blood pressure shows a distinct drop when changing from the reclining position to the standing position in both groups.

4. The lying blood pressure following exercise (varsity practice) is higher than the normal lying blood pressure.

5. The standing blood pressure following exercise (varsity practice) is lower than the normal standing blood pressure.

6. The winter blood pressure averages vary slightly from those of the fall.

7. A very distinct rise in blood pressure tests after exercise is noted for the winter athletes when compared with the fall athletes—twenty points lying and nine points standing, increase in winter.

8. Indoor work might influence winter results in the tests.

9. The swimming, track, and basketball taken as separate groups, show a decrease in blood pressure upon standing after varsity practice, track and basketball showing the greater decrease.

10. During the Schneider Tests the blood pressure of the swimming and track groups show an increase on rising. The basketball group shows a decrease.

11. Swimmers have a lower difference in heart rate lying and standing than the other groups.

12. Thirty-four per cent of the non-athletes did not return to normal heart rate at the end of the second minute after exercise (twenty knee-raisings), and 22.6 per cent of the athletes failed to return.

13. The study of the heart rate for two and a half minutes, in its recovery following exercise, show both groups about the same.

14. In the comparison of the horizontal and standing blood pressure for the athlete following the Schneider Test, a majority decreased. After varsity practice, the blood pressure shows two men increasing and the remainder decreasing or remaining the same.

15. The non-athlete shows about an equal number increasing and decreasing in the blood-pressure test when changing from reclining to standing position.

This study was continued in the spring season with only slight variations from the results obtained in the fall.

The summary follows:

1. Pulse rate for the athletes is much lower than for the non-athletes.

2. Difference between heart rate lying and standing is greater for the athletic group.

3. The pulse rate following exercise is lower for the athlete.

4. The average systolic pressure after twenty knee-raisings is greater for the athlete, but the difference between the lying and standing pressures is less for the athlete.

5. Systolic pressure following varsity practice decreases on changing from the lying position to the standing position.

6. Both groups show a gain in blood pressure when changing from the lying position to the standing position during the Schneider Test.

7. One hundred per cent of both athletes and non-athletes increase in heart rate for the first minute after exercise (twenty knee-raisings).

8. A greater per cent of non-athletes fail to return to normal heart rate than the athletes during the next minute and a half.

9. During periods 91–120 seconds and 121 + seconds after exercise, a larger percentage of both athletes and non-athletes either remain the same or decrease in heart rate than that which increases.

In addition to the study of circulation, a study of the weight of both athletes and non-athletes was attempted. Both groups had their weights recorded once during the day and the athletes had an additional weight test after varsity practice. Comparisons were made of the averages of both athletes and non-athletes for each of the three seasons, and in the case of the athlete the weights before and after practice were studied.

From the results of the test a comparison of the average weights of athletes and non-athletes for the three seasons, fall, winter, and spring, it is evident that the non-athlete averages less in weight in all seasons than the athlete. During the winter the non-athlete gains while the

athlete shows a loss of 7.9 lbs. In the spring the reverse is noted; the athlete gains while the non-athlete loses. The reason for this variation is hard to determine since the athletic groups change for each season. Of the three groups of athletes examined, we find those in winter sports having the lowest weight. This seems to indicate that men lighter in weight choose such sports as basketball, swimming, and track. The fall average shows the heavy man reporting for football while the spring averages, including such sports as baseball, track, or tennis, show a slight increase in weight over the winter. It is probable that the study of track and tennis alone would find this group showing lower weight averages than baseball.

Following are some of the results that were found in this study:

1. Generally the weight after varsity practice in all sports decreases.
2. Swimmers show very little loss of weight during practice. Some individuals do not lose at all.
3. Weight of football men increases during the fall.
4. Track shows greater loss in weight than basketball or swimming.
5. The swimmers show a gain in weight during the winter season while the track and basketball men average a loss.
6. The non-athletic group shows only slight variations in all seasons.

The general conclusions drawn from this study are:

That the athlete has a lower average than the non-athlete in the majority of items in the Schneider Tests. In the fall the athlete is lower in every case with the exception of the difference in blood pressure on changing from the reclining to the standing position. The athlete shows an average loss of 2.6 while the non-athlete averages but .1 loss. During the winter and spring we find the same results in this phase of the Schneider Tests, the difference in the blood pressure lying and standing is greater for the athlete. In fall and winter the average difference is a loss; in the spring the average difference is an increase. According to Schneider,[1] "a systolic pressure which falls on changing to the standing position from the reclining, is an indication of fatigue, staleness, or weakness." The largest average decrease of the athletes occurs in the fall and is 2.6, the smallest is .1 in the non-athlete in the fall. It appears from this comparison that the athlete, in the football season of the year, differs to the greatest extent from the non-athlete, which fact might lead one to suspect that football is a strain on those participating.

The blood pressure in the spring is another exception where the athlete averages higher than the non-athlete, although the variation is but slight. However, in the case of both athletes and non-athletes the blood pressure tests fall within the range of blood pressure recognized as an indication of good condition. When comparing the three seasons, we find very little variation, in the case of the athlete the greatest variation is in the heart rate after exercise which in the winter is 11.5 higher

[1] E. C. Schneider, "A Cardiovascular Rating as a Measure of Physical Fatigue and Efficiency," *Journal of the American Medical Association*, Vol. 74, Page 1508.

than the lowest average (the fall), in the non-athletes the same item, heart rate after exercise, shows an increase in the spring of 8.7 over the fall or lowest heart rate after exercise. To sum up the preceding statements we may state that from the results of the Schneider Tests, the reaction of heart rate and blood pressure, the athlete seems to be in a better physical condition than the non-athlete.

Both heart rate and blood pressure show a decided increase after exercise consisting of 20 knee-raisings in 5 seconds, after which the heart rate was registered, while the exercise before the blood-pressure tests was the different varsity sports. We find very little variation in the 3 seasons of the increase in the heart rate after exercise above the normal heart rate; in the fall 20.5, winter 27, and spring 28.9. In considering the return to normal heart rate, however, there is more difference. In the fall all the athletes return at the end of the second minute after exercise, while in the winter 22.6 per cent fail to do so and in the spring 15.8 per cent do not return to normal heart rate at the 91–120 second period. The blood-pressure tests taken after varsity practice show the winter averages much higher than the other 2 seasons. The blood pressure standing after varsity practice drops from the lying blood pressure in the winter as much as 13.6, and in the fall only 3.3; while the normal lying and standing blood pressure shows a decrease of only .9 in the winter and 2.6 in the fall. One might conclude from these tests that strenuous exercise causes a great increase in blood-pressure tests over the normal tests. A decided decrease is evident when changing from the lying to the standing position. This has been found to be characteristic of all athletes, whether this is a favorable sign or not cannot be determined from our tests here.

The results compiled of the men in outdoor sports and compared with those compiled for men in indoor sports indicate that indoor work takes more out of an athlete than outdoor work. In practically every case the median and average show a higher grade of physical efficiency in the fall and spring than they do in the winter. The heart rate, upon its recovery following exercise, has a greater number in the winter failing to return to normal than in the other two seasons.

The weight of the athlete generally decreases while that of the non-athlete shows very little variation. The study of the football men in the fall shows their weight gaining or remaining the same. In the winter the athletic group as a whole shows a loss, but when separated into swimming, track, and basketball sections, we find that the swimmers gain for the season while the track and basketball groups lose. Spring also shows a loss in weight for the athlete. The non-athlete shows variation in weight during the three seasons. Following varsity practice, track shows the greatest loss in weight of any of the winter groups. It is interesting to note from this study that the swimmers show very little loss of weight during practice and some individuals do not lose at all. No apparent reason for this can be determined.

The Validity of Footprints as a Measure of Vertical Height of the Arch and Functional Efficiency of the Foot*

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THE PROBLEM

Need to Validate Footprints.—There is a need to validate the taking of footprints. Dozens of persons are industriously engaged in the taking of footprints and offer various explanations as to why they are taken. These reasons usually include the following points in justification of the procedure:

1. That they are motivating to pupils in directing attention to foot mechanics as an element of "posture-consciousness."

2. That high arches indicate better feet which are stronger, more elastic, and more efficient in all natural uses of the feet.

3. That low arches indicate conditions which are coincident with pain, quick fatigue, or inefficiency in hard usage of the feet.

4. That the footprints enable the relative status of the foot condition to be known so that improvement or retrogression can be objectively measured in corrective work.

These reasons sound plausible enough, but, unfortunately, there is insufficient proof in the literature on all items, except the first, to which one might point who wanted to justify the time and expense of such a procedure, particularly as used on a large scale in public school systems.

Clinical opinion has always supported the viewpoint that flat-footed pupils are, as a group, relatively more awkward, less efficient in foot skills, and complain more quickly of fatigue or pain when much work is done on the feet. Lowered arches when accompanied by some pronation, as evidenced by the in-slanting of the heel cord or inward bulging of the medial side of the arch opposite the scaphoid bone, are generally associated with weak and painful feet. Pupils are readily assigned to corrective classes on evidence of flat-foot.

Ordinary methods make it hard to distinguish between a "real" weak foot and an "apparently" weak foot as indicated by footprints or superficial inspection. It is well known that the pedograph[1] print

* In this study the writer acknowledges the help of C. W. Davis, who helped with the sandbox prints, and also assistance from John Squires, Haskell Elder, and William Holmes, who helped with some of the statistical work.

[1] Pedograph, Scholl Mfg. Co., 62 West 14th St., N. Y.

shows the fleshy pad of the plantar surface of the foot and not the bony alignment of the arch. If the plantar muscles are relatively strong, there will be relatively more flesh present underneath the arch. This might cause an "apparent" flat-foot, whereas, the foot is in fact a strong and well-muscled one. The finding of a relatively large number of good athletes with "apparent" flat-foot in the body mechanics examinations of Springfield College men given each fall by the writer led to a more critical examination of this condition. No one was found who could really prove the functional significance of footprints, although many teachers were interviewed who were industriously engaged in taking the prints. Writers of modern books on tests and measurements advocate taking footprints but advance little or no evidence as to their functional significance.

Pain, fatigue, and poor performance on the feet are good criteria for condition of the feet. Any proved relation between the arch and these conditions would be significant. Are any of these conditions reflected consistently through footprints? Are footprints a valid measurement of any of these functional conditions?

Realizing that the significance of a test is not proved until it is correlated with something, it was decided to correlate the footprint arch angle with other measurements of the arch and also a large number of foot-skill performances in which the feet are most actively used, hoping thereby to find evidence to validate the procedure of taking footprints.

Objectives of Study.—The definite objectives of this study are:

1. Investigation of the footprints[2] with the measurement made in the horizontal plane as a valid measurement of the height of the arch (longitudinal) in the vertical plane.

2. Comparison of the angle method[3] (Illus. III) of measuring the arch with two other methods, i.e., (1) a linear measure of the arch in the horizontal plane, made at the widest portion of the white space, the measurement being perpendicular to a tangential line on the medial side of the foot touching the heel and the first metatarsal joint at the base of the big toe (Illus. IV); (2) the sandbox method of measuring the vertical depth of the arch imprint in moist sand (Illus. II).

3. Effect of the foot size on the measurement of the longitudinal arches of college men.

4. Significance of the measurements of the arch as related to functional efficiency of the foot in jumping, running, lifting, weight bearing, balancing, strength and flexibility tests. ***This is the biggest question about footprints. They may be highly reliable and objective but they***

[2] Made with the pedograph, *op. cit.*

[3] H. Harrison Clarke, "An Objective Method of Measuring the Height of the Longitudinal Arch in Foot Examinations," *Research Quarterly*, IV: 3 (Oct., 1933); also L. Schwartz, R. H. Britten, and L. R. Thompson. "Studies in Physical Development and Posture," *U. S. Health Bulletin No. 179*, p. 23, 1928.

are meaningless unless they tell something definite about the feet which is of functional significance. We might just as well be measuring the width of the nose.

VALIDITY OF THE ARCH ANGLE AS A MEASURE OF VERTICAL HEIGHT OF THE ARCH

No one would attempt to measure the height of a building by measuring its width. Relatively, however, buildings may be ranked in height by measuring width in the degree to which height is directly proportional to width. The footprint is measured in the horizontal plane. To what degree can this measurement be taken to be proportional to vertical height? Vertical height has been stressed by those who have analyzed the mechanics of the foot as being functionally significant. If this is true, we should be certain that the true vertical height is being measured, or at least, some measurement which is directly proportional to this height.

Clarke,[4] at Syracuse University, studied the arch-angle method of measuring the pedograph prints, following up the work previously done by Schwartz,[5] of the U. S. Department of Public Health. Schwartz invented the footprint angle, presumably as a device to eliminate the influence of foot size on the measurements. Clarke demonstrated that a slight refinement of Schwartz's method gave results which were remarkably reliable[6] and objective.[7] No evidence was presented in either of these studies to show that the arch angle was a significant measure of the functional condition of the foot.

The Sandbox Method for Measuring Vertical Height.—The writer conceived the idea of measuring the vertical height of the arch by means of measuring imprints of the foot made in moist sand. This project was assigned to C. W. Davis, a senior project student in body mechanics in 1933. Following suggestions given to him, Davis constructed the sandbox shown in Illus. I.

This sandbox permitted making an exact imprint of the foot which would show the ***height of the arch*** as related to the lowest points of depression under the heel and the first metatarsal joint at the proximal end of the big toe. (Illus. II) The height was secured by slicing a triangle down through the central arch mound of sand until the heel and medial ball depressions were just reached. This slicing was done in a uniform manner. It was found that the triangle could always be aligned with the center of the back of the heel and the center of the base of the big toe. The beach sand was moistened just enough to take

[4] Clarke, *op. cit.*

[5] Schwartz, *op. cit.*

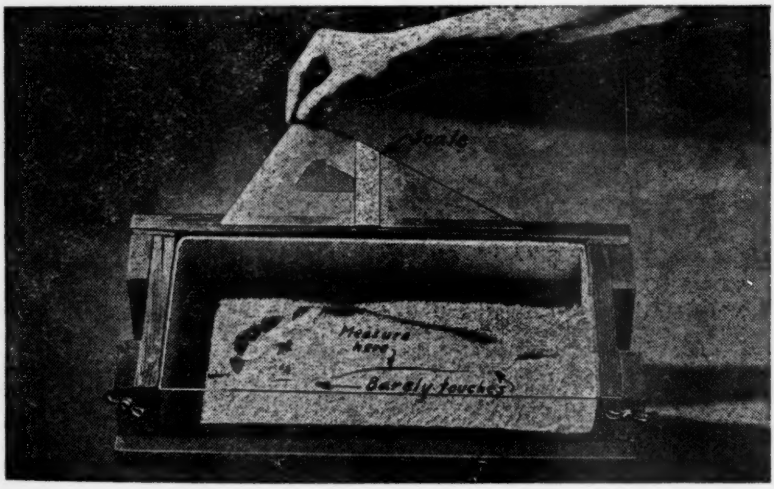
[6] "reliable," i.e., consistently the same as repeated by the same examiner under the same conditions on the same subject or subjects.

[7] "objective," i.e., consistently the same as repeated by different examiners under the same conditions on the same subject or subjects.

a good print. Between prints it was loosened and smoothed over. The vertical height of the arch was read on a millimeter scale pasted to the center of the triangle.

Correlation of Vertical Height with Arch Angle.—The arch angle

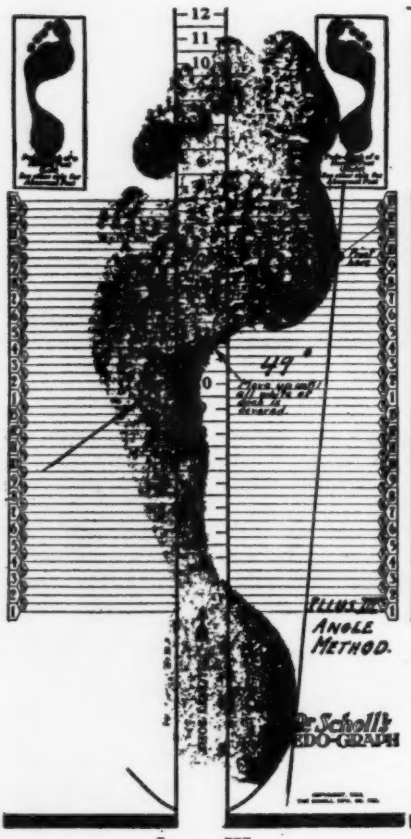
ILLUS. I.—The sandbox for footprints.



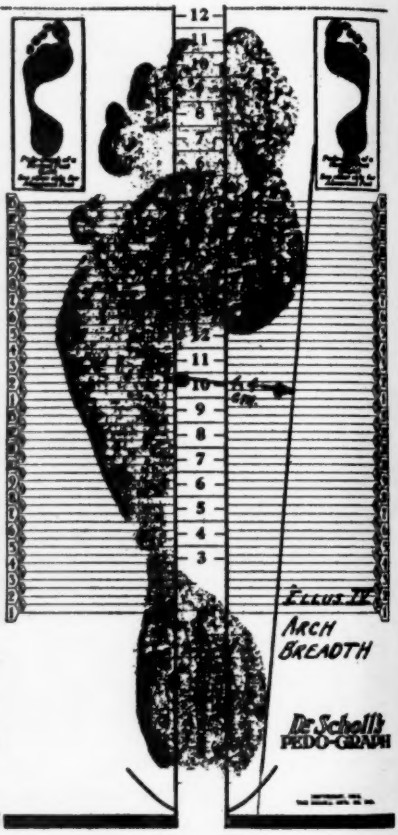
ILLUS. II.—Method of measuring the sandprints.

was carefully measured by scaling 132 pedograph prints, using Clarke's method (Illus. III), taken on Springfield College freshmen. The vertical height was determined by the sandbox method. The correlation between the arch angle and arch height was .857 ± .016 and .958 ± .007 on two sets of data. With the very high reliability indices of both tests this cannot be raised significantly by correction for at-

tenuation.[8] Roughly, this correlation means that the arch angle measures perfectly the vertical height in 58.0 per cent of the cases, (using $\sqrt{r_1^2 + r_2^2}$) and the probable error in any case would not exceed .568 cm. This estimate is made by using the predictive index $1 - \sqrt{1 - r^2}$ which converts the correlation into a rough percentage score.[9]



ILLUS. III



ILLUS. IV

Regression Equation to Convert Arch Angle into Vertical Height.— Using the two variable form of the regression equation,[10]

$$y = r\frac{\sigma y}{\sigma x}.x$$

$y =$ (A) arch angle (Clarke's Method) in degrees.

$x =$ (H) vertical height of arch in cm.

[8] "Attenuation," a correction for lack of reliability in the test data to be used when the true relationship between two variables is sought, see H. E. Garrett, *Statistics in Psychology and Education*, pp. 211-213. New York: Longmans, Green & Co., 1933.

[9] F. R. Rogers, *Fundamental Administrative Measures in Physical Education*, pp. 63-65. Newton, Mass.: Pleiades Co., 1932.

[10] Garrett, *op. cit.*, p. 174.

Substituting the values of the correlation and the standard deviations,

$$A = .900 \times \frac{9.55}{1.93} \times H \text{ (cm.)}$$

$$H \text{ (Cm.)} = \frac{A}{44.4} \text{ (Deviation form)}$$

$$H \text{ (Cm.)} = \frac{A - .13}{44.4} \text{ (Score form).}$$

The linear arch breadth (B) can be computed from the angle closely enough by using the formula,

$$B \text{ (cm.)} = .0739\, A \text{ (degrees)}$$

Similarly, the arch angle can be computed by the formula,

$$A = \frac{B \text{ (cm.)}}{.0739}.$$

COMPARISON OF THE METHODS FOR MEASURING THE ARCH

It is interesting to know if the arch-angle method is any better than the sandbox vertical height method or the direct method of scaling the greatest perpendicular linear distance between the tangential line and the isthmus of the arch (Illus. IV).

The intercorrelations between arch angle (Clarke's Method–Illus. III) and arch height (sandbox method) were .857 ± .016 and .958 ± .007 on two sets of data collected on Springfield College men. These correlations are so high that it would make little difference which scheme was used. This result forecasts the prediction that foot size is not a major variable affecting the arch measurement within the limitation of the scope of this data, a relatively homogeneous group of college men.

Comparative Reliability and Objectivity of the Pedograph and Sandbox Methods.—The sandbox method produced results comparable to the scaling of pedograph prints in reliability and objectivity. The following table gives the comparative results:

	Pedograph Foot Angle (Clarke's Method)	Sandbox Method
Reliability	A. D. = .261 degree. Av. Per Cent Error = .502% r = .971 (135 cases)	A. D. = .016 cm. Av. Per Cent Error = 1.55% r = .98
Objectivity	A. D. = 1.37 degrees. Av. Per Cent Error = 1.09% r = .95 (135 cases)	A. D. = .020 cm. Av. Per Cent Error = 1.94% r = .97

The correlation between arch angle with arch breadth was .854 ± .019 and between vertical height of the arch and arch breadth .840 ±

.019. These were high when corrected for attenuation (.90). It is obvious that either of the three methods could be used on this relatively homogeneous group of young male adults with little advantage for any one method.

Norms for Foot Measurements of Springfield Men.—In order to facilitate rating any student the following table is given which is based on data collected on Springfield college students, all male and majoring in physical education. (Based on 800 prints and 132 sandbox tests.)

T-Scale	$+3\sigma$	$+2\sigma$	$+\sigma$	Mean	$-\sigma$	-2σ	-3σ
Percentiles	99.87	97.72	84.13	50	15.87	2.28	0.13
Arch Angle (degrees)	68.91	59.36	49.81	40.26	30.71	21.16	11.61
Sandbox Vertical Height (mm.)	15.24	13.31	11.38	9.45	7.52	5.59	3.66
Computed Vertical Height (mm.)	15.5	13.4	11.2	9.06	6.92	4.75	2.61
Arch Breadth (cm.)	5.1	4.39	3.68	4.05	2.98	1.56	.74
Computed Arch Breadth (cm.)	6.45	5.65	4.85	4.05	3.25	2.45	1.65

Arch Angle	Percentile	Arch Angle	Percentile
69	99.9	38	45
61	95	36.5	40
55	90	35	35
50	85	33.5	30
49	80	32	25
48	75	31	20
46.5	70	30	15
45	65	24	10
43.5	60	18	5
42	55	12	0.1
40	50		

FOOT SIZE AS AFFECTING THE ARCH MEASUREMENTS

The use of angles or linear distances has always been beclouded, according to some leaders in body mechanics, by the variable size of the feet in any group of subjects. It is interesting to see what this effect amounts to in the case of college men whose feet varied 3.3 to 4.5 inches

in width and from 9.2 to 11.0 inches in length. The following correlations were obtained:

Foot length with arch angle	$r = .055 \pm .066$
Foot length with arch breadth	$r = .085 \pm .066$
Foot length with vertical height of arch	$r = -.154 \pm .065$
Foot width with arch angle	$r = .051 \pm .066$
Foot width with vertical height of arch	$r = -.082 \pm .066$
Foot width with arch breadth	$r = -.129 \pm .065$

These correlations are insignificant. There may be a very slight tendency for men with longer and wider feet to have flatter prints.

THE LONGITUDINAL ARCH AS RELATED TO EFFICIENCY IN FOOT SKILLS

The foot is used vigorously in such events as running, jumping, weight bearing, shot putting, lifting, and balancing on the balance beam. Do the persons who are most efficient in these activities have the highest arches? If the arch is important in springing or indicative of functional efficiency, it should be reflected in measurements of performance in these events, because all of these events use the feet vigorously. The following correlations have been secured from data obtained on Springfield men:

Jumping:	
1. Arch angle with height in the Sargent vertical jump	$r = -.033 \pm .066$
2. Vertical height of the arch with height in the Sargent vertical jump	$r = -.114 \pm .067$
3. Vertical height of the arch with standing broad jump	$r = .170 \pm .066$
(Three separate sets of data.)	$r = .177 \pm .066$
	$r = .110 \pm .066$
Running:	
1. Arch angle with speed in the fifty-yard dash	$r = -.054 \pm .066$
(Two sets of data.)	$r = -.050 \pm .066$
2. Arch angle with speed in the 440-yard run	$r = .245 \pm .066$
3. Vertical height of the arch with speed in the 440-yard run	$r = .297 \pm .066$
Weight Bearing and Lifting:	
1. Arch angle with body weight	$r = .040 \pm .066$
2. Vertical height of arch with strength of lift on back and leg dynamometer (sum of back and leg strengths)	$r = -.241 \pm .066$
(Another set of data.)	$r = -.232 \pm .066$
3. Vertical height of arch with shot-put distance	$r = -.052 \pm .066$
4. Arch angle with leg strength	$r = -.194 \pm .066$
5. Arch angle with back strength	$r = -.127 \pm .066$
6. Arch angle with center of gravity	$r = -.123 \pm .080$
7. Vertical height of arch with center of gravity	$r = -.171 \pm .092$
Balance:	
1. Arch angle with balance scores on balance beam test	$r = .146 \pm .066$
Flexibility:	
1. Arch angle with flexibility of the ankle joint	$r = .014 \pm .066$

Foot strength:

1. Elbel (1928)[11] and Gruenberg (1929)[12] studied the arches as related to foot strength and both reported an insignificant relationship.

The results of these correlations are not impressive. The only relationships seem to be (1) with the 440-yard run, the maximum correlation which can be claimed is + .324 after attenuation correction; (2) with strength of the leg and back muscles, the correlations being $r = -.241 \pm .066$ (combined), $r = -.194 \pm .066$ (leg) and $r = -.127 \pm .066$ (back). The highest correlation which can be claimed after attenuation correction is $-.271 \pm .066$. This indicates a slight negative relation between strength of the extensor muscles of the back and leg. The stronger men seem to have slightly stronger extensor muscles and possibly stronger plantar flexor muscles as the tests involve these also. In general there is a good correlation between muscle groups so intimately related.

The correlations of the center of gravity[13] with the arch show that there is a slight tendency for the men with flatter prints (and stronger men) to carry their weight more forward on the balls of the feet, which indicates better condition.

PAIN AND FATIGUE

Experiments in this field have not been exhaustively carried out. The correlation of +.324 with the 440-yard run may indicate a more fertile field of investigation. The writer regrets that data on 880, mile, two-mile, and six-mile running is not available in large enough quantity to carry out the correlations at this time. This will have to be listed as a future problem.

Out of 600 men tested in the past 5 years there are approximately 150 of these men with arch angle under 21 degrees. Although the greatest number of these men have been varsity athletes and all of them did active sport work daily, there have been not more than 4 or 5 complaints of pain. Some men with the lowest arches are outstanding athletes in football, sprinting, jumping, cross-country running, and basketball. These sports demand the hardest usage of the feet.

CONCLUSIONS

1. The arch angle, sandbox, and linear breadth methods of measuring the longitudinal arch all correlate about .90 with each other and may be used interchangeably on the feet of college men with insignificant differences.

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[11] E. R. Elbel, "A Study in Short Static Strength of Muscles," p. 52. Master's Thesis, Springfield College, 1928.

[12] A. L. Gruenberg, "Short Static Contractions as an Aid in Corrective Gymnastics," Thesis, Int'l Y.M.C.A. College, Springfield, Mass., 1929.

[13] T. K. Cureton, and J. S. Wickens, "Center of Gravity in the Antero-Posterior Plane and Its Relation to Posture, Physical Fitness, and Athletic Ability." See pp. 93-105 of this SUPPLEMENT.

2. The regression equation for converting the arch angle in the horizontal plane (A) into linear height in the vertical plane (H) is,

$$H \text{ (cm)} = \frac{A \text{ (degrees)}}{44.4}.$$

3. The regression equation for converting the linear arch breadth (B) into arch angle (A) is,

$$B \text{ (cm)} = .074\, A \text{ (degrees)}$$

4. The regression equation for converting the arch angle (A) into linear breadth (B) is,

$$A \text{ (degrees)} = \frac{B \text{ (cm)}}{.074}.$$

5. Norms are given for the longitudinal arches of Springfield College men in terms of three different sets of measurements, each a different method and a more detailed percentile scale for arch-angle scores.

6. Foot size does not affect significantly the longitudinal arch measurements as made on these college men.

7. Twenty-one correlations of the longitudinal arch with foot-skills show:

a) Insignificant correlations with jumping. The highest correlation being $+ .170 \pm .066$.

b) Insignificant correlations with speed running (50 yards), the correlation being $-.054 \pm .066$.

c) Some positive correlation with 440-yard running $+ .324$ (corrected), probably indicating that the men with flatter prints have a tendency to fatigue more quickly which is true of most big-muscled men.

d) Some negative correlation with lifting strength tests $- .271 \pm .061$ (corrected), probably indicating a slight tendency for the stronger men to have flatter prints, perhaps because of stronger and larger plantar muscles, causing the muscles to be flatter.

e) Some slight negative correlation with carrying the center of gravity more forward, which has been proved in another experiment to indicate better condition and power capacity ($- .186 \pm .066$).

f) Insignificant relationships with foot strength as measured by Gruenberg (1929), ankle flexibility, and balance tests.

g) Some few cases of fatigue or slight ache in less than 5 per cent of the lower 15 per cent of the Springfield men, approximately .8 of 1 per cent of the entire group of 600 cases measured over a period of 5 years.

h) The tremendously large number of defective feet reported throughout the literature is probably an exaggeration due to all persons with low arches, as measured by footprints, being classed as defective. Men have probably been excluded from the army and chil-

dren put in corrective classes who had the strongest feet.

i) Other tests of functional significance need to be developed for the feet. Four of these which have given preliminary possibilities are (1) the amount of adduction of the big toe toward the median line of the foot, (2) the width of the foot, probably in proportion to length, (3) the amount of sag in the arch and spread of the width of the foot under the body weight or extra load, and (4) the position of the foot under weight as indicated by the angle of the heel cord and the inward bulging of the medial side of the arch.

j) It is believed that the mechanics of the arch of the foot has been somewhat misunderstood because of the general dearth of statistical evidence, such as that presented in this paper. Low arches have been assumed to mean weak feet without just basis in a great many of the cases. To many, strong muscles have meant "short" muscles, and these, acting like a bowstring across the plantar surface of the foot, support the arch. The writer believes, after studying the data in these experiments, that this is a false conception. Muscles may be strong without being "short." Most great athletes have long-range muscles, good flexibility, and at the same time good strength. Morton[14] has maintained that the muscles have little to do with the support of the arch and that the support is almost wholly due to ligaments. *It is certain that footprints alone, as taken on the pedograph, are not sufficient basis for an accurate classification.* There seem to be just as many men with high arches and weak feet as there are with low arches and weak feet as judged by the prints.

[14] Morton, "Mechanism of Normal Foot and Flat Foot," *Journal of Bone and Joint Surgery*, VI:2 (April, 1924).

Reliability and Objectivity of the Springfield Postural Measurements

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THE PROBLEM

COMPARISON of "Subjective" with "Objective."—The relative precision of the "subjective"[1] as compared with the "objective"[2] schemes of grading posture has always been a problem for debate. It is obvious that the first will vary with the training and experience of the examiners, the latter with the adaptability and refinement of the measuring instruments as well as the expertness of their manipulation. There is undoubtedly a place for both schemes depending upon the circumstances which exist. It may be mentioned that in the past the *clinical judgment* of the examining physician was used as the principal guide. The modern age has seen great advancements in the science of measurements in every field. Even the physician has come to rely on X-ray, optical, blood, and metabolism tests, and a host of others to make reliable diagnoses. Likewise, educators have come to depend upon tests, as evidenced by intelligence tests, personality rating scales, emotional reaction tests, vocational aptitude tests, etc.

The task of measuring posture has been persistently pursued in the past decade for the following reasons:

1. Educators are demanding a more complete validation of the program with more "objective" demonstration of results.

2. Educational procedures are becoming more scientific with a great deal more measurement procedure in general.

3. The validity of postural ratings has been seriously questioned and also that posture can be significantly changed.

4. Medical examiners' "opinions" have been shown to vary widely and under test the reliability and objectivity of their ratings of physique, nutrition, and condition demonstrate the need for measurement.[3,4]

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[1] "Subjective" is used here to mean the procedure of guessing the grade after a visual inspection, based upon the opinion of the examiner.

[2] "Objective" is used to denote the procedure of giving a rank position to each subject on the basis of measurements made with accurate and reliable instruments.

[3] Raymond Franzen, *Physical Measures of Growth and Nutrition*, p. 5. New York: American Child Health Assn.

[4] James G. Bliss, "The Validity of the Medical Examiner's Rating in the Administration of Physical Education," *American Physical Education Review*, XXXII:10 (Dec., 1927), 707-717.

5. Opinions as reported in the *A, B, C, D* system are not very susceptible to accurate statistical analysis. The precision of this system is doubted.

6. Evaluating posture with a single letter, such as "B," has left hundreds of records which are valueless if any specific segment of the body is studied in detail.

Significance of Reliability and Objectivity Coefficients.—The precision of a test is never known until its *reliability*[5] and *objectivity*[6] is determined by experiment. Strange to say, there is almost a dearth of these indices for the "subjective" and "objective" posture rating schemes. Schwartz, Britten, and Thompson[7] include five reliability coefficients for five posture angles but their study involved a four-month interval between the successive tests and it is expected that the coefficients would be somewhat low and the figures are hardly fair to the tests.

The most serious need for reliability and objectivity coefficients is encountered in studying the significance of any postural item, such as "poke neck," "round shoulders," "hip slouch forward," "protuberant abdomen," "hyperextended knees," "lordosis," "kyphosis," "scoliosis," "flat-feet," or any other defect. *When measures of any one of these things are correlated with acceptable criteria, the result will never be higher than the reliability coefficient of the postural item.*

There are two outstanding reasons why attempts to correlate posture with health, scholarship, intelligence, athletic activity, organic condition, and similar criteria have mostly failed.[8] In each case where posture has been so correlated the weaknesses have been:

1. The reliability coefficients of the postural measurements have been unknown, and have mostly been far below the accepted research standard of .80.

2. Posture has been interpreted mostly as being the position of the chin and the chest rather than a series of precisely known, understood, and carefully measured separate elements. The rough allotment of an "*A*" in body mechanics means excellence in carriage of all segments. This cannot be determined with certainty until more is known about the correlation of mechanical alignment with organic functioning of each segment in question. One at a time, each of the postural elements must be correlated with a large number of criteria. The reliability and objectivity of the measurements must be known to interpret the correla-

[5] "Reliability" is defined as the degree of consistence of the measurements when repeated by the same examiner on the same subjects under the same conditions.

[6] "Objectivity" is the similarity of the measurements when repeated by different examiners on the same subjects under similar conditions.

[7] Louis Schwartz, R. H. Britten, and L. R. Thompson, "Studies in Physical Development and Posture," *Public Health Bulletin, No. 179*, Washington, (June, 1928), 9-13.

[8] G. G. Deaver, "Posture and Its Relation to Mental and Physical Health," *Research Quarterly*, IV:1 (March, 1933), 221-228.

tions resulting. With these known the "attenuation"[9] correction may be applied and a true estimate of the relationship secured. *There may be such relationships and many experts who have studied posture and health for years believe that there are but they remain largely unproved.*

Experiment to Test Situation at Springfield.—Every fall the entering freshman class and the seniors are given thorough body mechanics examinations. It was decided to have the seniors examined by three different examiners in different rooms, each examiner a graduate in physical education and a specialist in body mechanics and corrective work. In order to systematize the grading and to secure numerical marks to simplify the correlation procedure, the following scheme was agreed upon:

1. That five separate items would be inspected: (1) the *head and neck*, grading "position"; (2) the *chest and abdomen*, grading relative alignment; (3) the *shoulders*, grading position; (4) the *spine*, grading alignment; and (5) the *feet*, grading general condition particularly of the arches.

2. Each of the five segments graded was allotted 20 points and each 20 points to be apportioned as follows:

a) Perfect condition ..... 20 points.
b) First degree or mild defect ..... 19 to 15 points.
c) Second degree or very noticeable defect ..... 14 to 10 points.
d) Third degree or serious defect which undoubtedly interfered with health or efficiency ..... 9 to 5 points.
e) Fourth degree or serious orthopaedic defect involving loss of use of part ..... 4 to 0 points.

This procedure was for the purpose of giving the subjective scheme every opportunity to show to best advantage. Each examiner put down a definite numerical estimate on each of the five segments graded. The entire experiment was repeated on the same men after an interval of one week. The reliability and objectivity coefficients were computed for the procedure. The results are as follows:

INSPECTION

1. *Objectivity Coefficients of Total Scores (1st Exam.)*
(total of all segments on 100 per cent basis—63 cases)
Cureton and Elder intercorrelated ..... $.556 \pm .068$
Cureton and Wickens intercorrelated ..... $.35 \pm .073$
Wickens and Elder intercorrelated ..... $.445 \pm .063$

2. *Reliability Coefficients of Final Scores (1st and 2nd Exams.)*
Cureton ..... $.565 \pm .053$
Wickens ..... $.566 \pm .053$
Elder ..... $.550 \pm .060$
Mean of both groups ..... .51
P.I. = .134

MEASUREMENT
Combined reliability and objectivity
$r = .883 \pm .018$
P.I. = .448

[9] See H. E. Garrett, *Statistics in Psychology and Education*, pp. 211-213. New York: Longmans, Green & Co.

The measurement scheme is nearly four times as good as visual inspection.

Franzen states that the reliability coefficient of any test should be at least .8 to justify its use.[10] This is, of course, governed by the kind of thing being measured and the relative state of development of tests in that field. A correlation coefficient as low as .5 means, however, that the judgments were only 13.4 per cent better than pure chance guesses. There is a tremendous difference between coefficients of .5 and .8, a difference equal to 37 per cent. The significance of any correlation coefficient may be determined by converting it into a rough per cent estimate by using the predictive index[11] ($P.I. = 1 - \sqrt{1 - r^2}$). This has been done hereafter in comparing the relative value of the "subjective" and "objective" coefficients.

Comparisons on Each Segment.—It is of interest to know how the judgments and measurements varied comparatively on each segment. Tables for this purpose are now given.

1. HEAD AND NECK

SUBJECTIVE	OBJECTIVE
Objectivity	*Combined Objectivity and Reliability*
(1) Cureton and Wickens .438 ± .067 (71 cases)	(1) Silhouettes scaled by three measurers, repeated on a second set of pictures taken one minute after the first. Angle formed by horizontal line through 7th cervical and line through 7th cervical and tragus. (Illus. I-A) ..... .705 ± .041 (74 cases) P. I. = .291
(2) Cureton and Elder.. .322 ± .073 (71 cases)	(2) Same as above but measurements taken one week apart .581 ± .054 (68 cases)
(3) Wickens and Elder.. .502 ± .061 (71 cases)	(3) Same as above but another set of data, two examiners, one week apart..... .553 ± .055 (68 cases)
Mean = .42 P. I. = .093	
Reliability	
(4) Wickens' Judgments. .320 ± .073 (74 cases)	(4) Scaling silhouettes with vernier calipers for horizontal distance between two vertical lines erected through the 7th cervical and tragus. (Illus. I-B) ..... .428 ± .068 (63 cases)
(5) Elder's Judgments... .475 ± .063 (74 cases)	(5) Same as (3) but using smaller complementary angle at top ..... .552 ± .056 (Illus. I-C) (69 cases)
(6) Cureton's Judgments .457 ± .068 (75 cases)	
Mean = .413 P. I. = .09	

[10] R. Franzen, *op. cit.*

[11] F. R. Rogers, *Fundamental Administrative Measures in Physical Education*, pp. 63-65. Newton, Mass.: The Pleiades Co., 1932.

(6) Using the mid-point of the neck as the reference point for the angle and measuring the same angle as in (1) ..... .325 ± .070 (Illus. I-D) (67 cases)

(7) Same as (6) but using complementary angle.

(8) As in (4) but using the mid-point of the neck for one vertical line (Illus. I-E) ..... .209 ± .077 (68 cases)

(9) Using horizontal distance between a vertical line through the 7th cervical and the contour of the flesh line at the middle of the neck. Scaled with millimeter ruler directly on rods. Correlated with (1) (Illus. I-F) ..... .502 ± .061 (69 cases)

These measurements show that the best objective scheme (1), shown in Illus. I-A, gives a combined reliability and objectivity coefficient of .705 ± .041 as compared with mean correlations of .42 on objectivity and .41 for reliability in the subjective scheme. *Converting these correlations to predictive indices, the objective scheme is 3.08 times as good as the subjective scheme for objectivity and reliability.*

These results also show that a poor mechanical scheme of measurement may yield results inferior to the "guessing" procedure. Method (1), Illus. I-A, has been demonstrated to be the best of several different methods for scaling the head and neck posture.

2. CHEST AND ABDOMEN

SUBJECTIVE

Objectivity

(1) Wickens and Elder.. .687 ± .043 (71 cases)

(2) Cureton and Elder.. .34 ± .073 (76 cases)

(3) Cureton and Wickens .27 ± .075 (75 cases)

Mean = .432

P. I. = .095

Reliability

(4) Cureton's Judgments .528 ± .060 (75 cases)

(5) Wickens' Judgments. .550 ± .061 (62 cases)

(6) Elder's Judgments.. .525 ± .060

Mean = .534

P. I. = .156

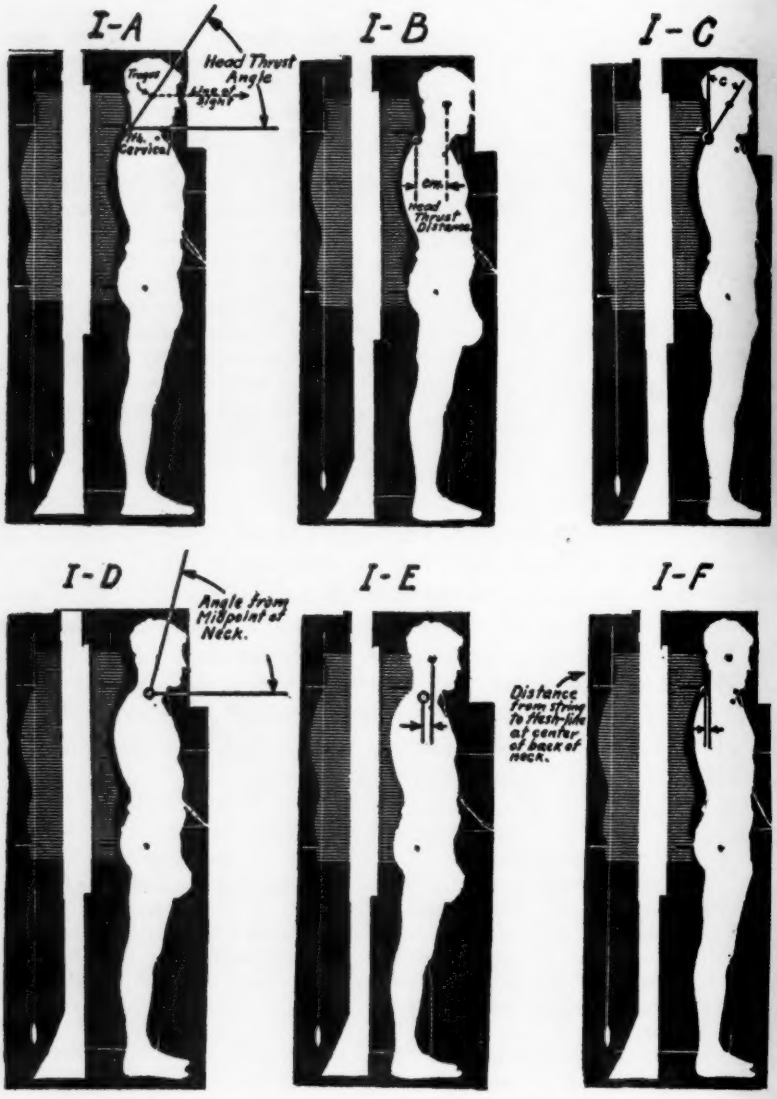
OBJECTIVE

Combined Reliability and Objectivity

(1) Kellogg's Chest Ratio Scaled on the Silhouettes. (Illus. II)

.884 ± .018

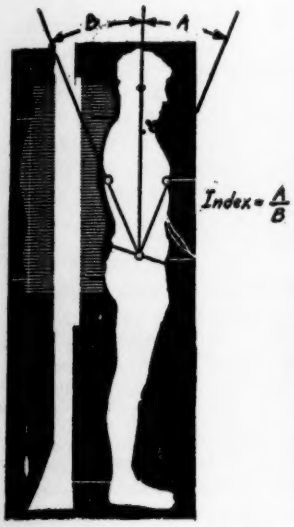
P. I. = .535



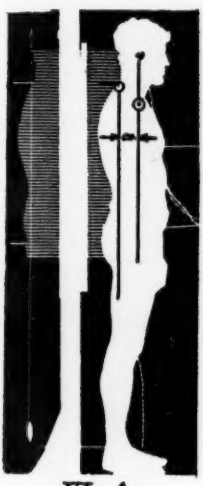
ILLUS. I

The Kellogg Chest Ratio[12] is very satisfactory in precision with a combined reliability and objectivity score of .884 ± .018. *It is 4.3 times as good for objectivity and 2.7 times as good for reliability as the visual inspection and subjective grading system.*

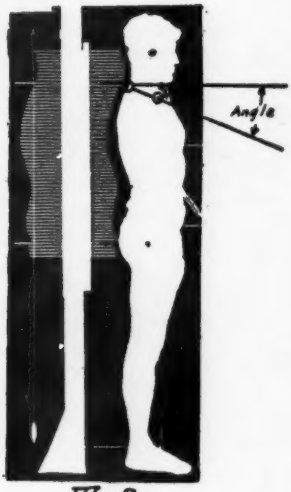
12 J. H. Kellogg, "Observations on the Relationship of Posture to Health and a New Method of Studying Posture and Development," *Bulletin of Battle Creek Sanitarium and Hospital Clinic,* XXI (Sept., 1927), 193-216.



Illus. II - Kellogg's Chest Ratio.



III-A



III-B

3. Shoulders

SUBJECTIVE

Objectivity

(1) Cureton and Wickens .330 ± .073
(71 cases)

(2) Wickens and Elder.. .462 ± .063
(71 cases)

(3) Cureton and Elder.. .040 ± .081
(76 cases)

Mean = .277
P. I. = .04

Reliability

(4) Cureton's Judgments. .382 ± 082
(75 cases)

(5) Elder's Judgments... .351 ± .069
(75 cases)

(6) Wickens' Judgments. .515 ± .061
(62 cases)

Mean = .416
P. I. = .09

OBJECTIVE

Combined Reliability and Objectivity

(1) Three examiners scaling silhouettes with vernier calipers, measuring horizontal distance between a vertical line through the 7th cervical and the front tip of head of the humerus. ..... .877 ± .022
(Illus. III-A)
(74 cases)
P. I. = .502

(2) As above but scaling angle made by a horizontal line through the 7th cervical and a line through the 7th cervical and the tip of head of the humerus. ..... .825 ± .029
(Illus. III-B)
(74 cases)

The objective scheme with a combined reliability and objectivity coefficient of .877 ± .022 is 13 times as good as the subjective scheme for objectivity and 5.79 times as good for reliability.

4. Spine

SUBJECTIVE

Objectivity

(1) Cureton and Wickens .329 ± .073
(71 cases)

(2) Elder and Wickens.. .202 ± .077
(71 cases)

(3) Cureton and Wickens .050 ± .075
(76 cases)

Mean = .193
P. I. = .02

Reliability

(4) Wickens' Judgments. .707 ± .041
(62 cases)

(5) Elder's Judgments.. .433 ± .068
(75 cases)

(6) Cureton's Judgments .577 ± .061
(74 cases)

Mean = .572
P. I. = .21

OBJECTIVE

Combined Reliability and Objectivity

(1) Kyphosis—measured across specific arc by scaling pictures with vernier caliper, two measurers .80 ± .022 Pictures one minute apart.
(74 cases)
(Illus. IV-A)
P. I. = .40

(2) Kyphosis—as in (1) except that pictures were taken one week apart and the measurements taken directly on the conformateur rods in true size ..... .603 ± .052
(74 cases)
(Illus. IV-A)

(3) Lordosis—measured across specific arc on rods by scaling with vernier calipers and with pictures taken one week apart ..... .67 ± .033
(75 cases)
(Illus. IV-B)
P. I. = .26

(4) Lordosis (another set of cases)—measured as in (3).. .066 ± .035
(71 cases)

(5) Lordosis—measured as in (3) except that the measurements were taken in true size from the conformateur rods ..... .621 ± .048
(74 cases)

(6) Lordosis—measured across the entire lower back to tangent line touching upper back and sacrum. .62 ± .040
(74 cases)
(Illus. IV-C)

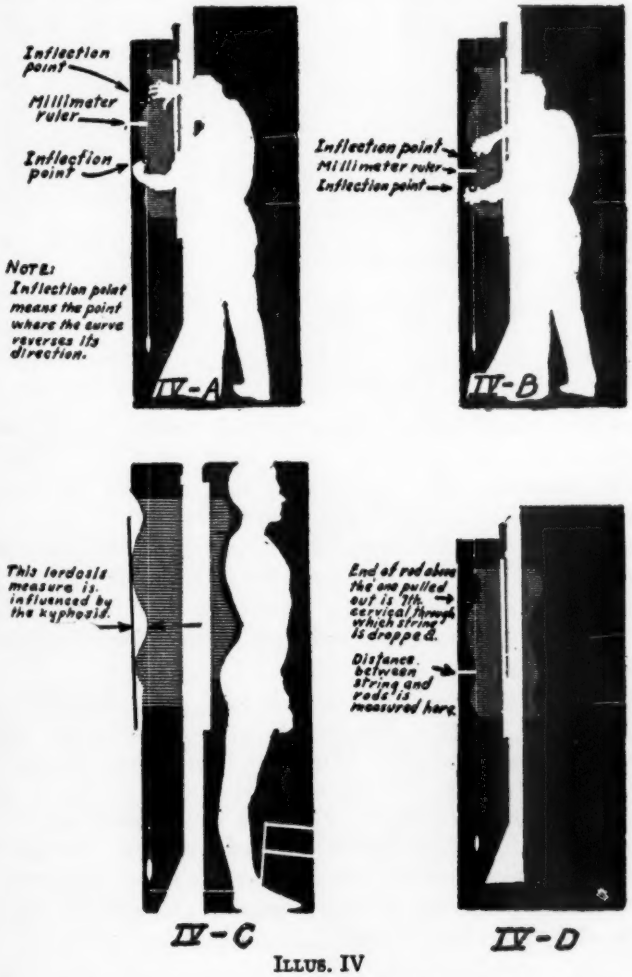
(7) Lordosis—measured by dropping a plumb bob through the tip end of the 7th cervical rod.. .33 ± .055
(74 cases)
(Illus. IV-D)

The best objective kyphosis measure has a correlation of .80 ± .022 and a predictive index of .40. *This is 20 times as good as the mean subjective objectivity correlation of .193 and predictive index of .02 and is twice as good as the mean subjective reliability correlation of .572 and predictive index of .21.*

The best objective lordosis measurement with a correlation of .67 and a predictive index of .26 *is 13 times as good as the subjective objectivity result with .193 for the correlation and .02 for the predictive*

index, and is 1.24 times as good as the subjective reliability coefficient of .572 and predictive index of .21.

One aspect of these measurements needs clarification. A previous study[13] demonstrated that there was a small error in scaling the pictures because of the smallness of the measurements. There was a certain subjective element even in using the vernier calipers. The experiments made in (2) and in (5) were for the purpose of seeing if the procedure could be improved by measuring the same distances directly on the rods where they were 16.21 times as large. It is believed that with practice this procedure would be better than scaling the pictures. It


Inflection point
Millimeter ruler
Inflection point
NOTE: Inflection point means the point where the curve reverses its direction.
IV-A
Inflection point
Millimeter ruler
Inflection point
IV-B
This lordosis measure is influenced by the kyphosis.
IV-C
End of rod above the one pulled out is 7th cervical through which string is dropped.
Distance between string and rods is measured here.
IV-D

ILLUS. IV

[13] T. K. Cureton, "Validity of Antero-posterior Spinal Measurement," *Research Quarterly*, II:3 (October, 1931).

has the disadvantage of requiring one operator to hold the string and another to take the measurement. (Illus. IV A and B) These correlations are lower than can be obtained because the work was hurried. The measurements were taken in class laboratory time and each section was limited to fifty minutes. The work had to be speeded up because only one "repeat" class could be allowed due to the pressure of other matters in the course.

5. FEET

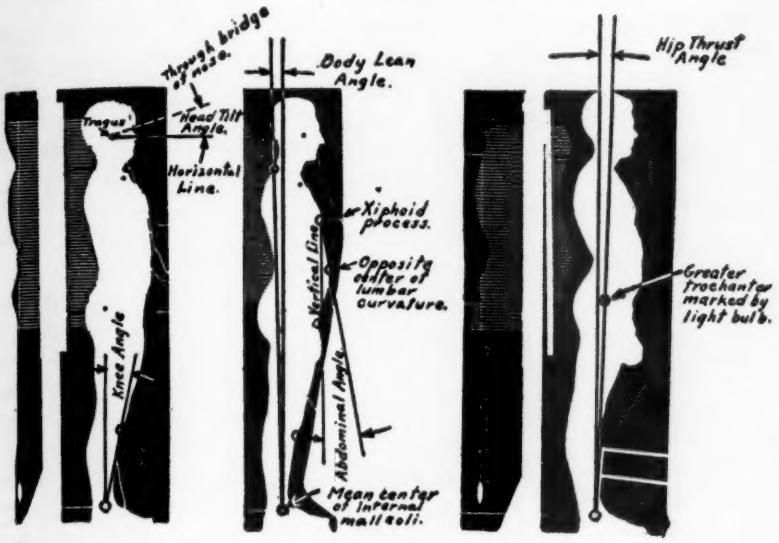
SUBJECTIVE		OBJECTIVE[14]	
Objectivity		*Objectivity*	
(1) Cureton and Wickens (71 cases)	.540 ± .060	(135 cases)	.95
(2) Elder and Wickens.. (71 cases)	.415 ± .068		P. I. = .688
(3) Cureton and Elder.. (76 cases)	.712 ± .047		
Mean = .56			
P. I. = .17			
Reliability		*Reliability*	
(4) Cureton's Judgments (74 cases)	.77 ± .038	(135 cases)	.971
(5) Wickens' Judgments. (62 cases)	.379 ± .073		P. I. = .76
(6) Elder's Judgments .. (75 cases)	.633 ± .050		
Mean = .59			
P. I. = .19			

The inspectional judgments on the feet yielded the highest mean correlations for reliability (.59) and objectivity (.56). *These correlations are, however, only one-fourth as significant for precision as the objective arch-angle scheme outlined by Clarke.*[14]

Development of the Postural Measurements.—The postural measurements outlined in this paper have been used at Springfield College for the past several years. They have been the subject of constant study regarding their precision and significance. The latter phase will be dealt with in a future paper.

The conformateur was first used in 1929 and a greatly improved model was built in 1931. The use of the small flash-light bulbs was introduced in 1933. The latter have proved to be a satisfactory method of locating the front tip of the shoulder, the tragus of the ear, and the greater trochanter of the femur. They are held in place by black elastics, each loop being fastened with a hook and eye. The pictures in silhouette form are much cheaper as made directly on Bromide No. 1 paper than the procedure of taking regular photographs requiring a negative. It is estimated that they cost about a cent each.

[14] Experiment by H. H. Clarke, *Research Quarterly*, (Oct., 1933). While the arch-angle scheme is precise, there are undoubtedly more significant measures of the foot, *re* 70-80, this SUPPLEMENT.



ILLUS. V.

While much work had been placed on the spinal curves, a major problem was the development of techniques for objectively scaling (1) head thrust forward, (2) head tilt, (3) forward shoulders, (4) hip thrust forward, and (5) hyperextended knees. These measurements were gradually developed and have been in the process of being studied as indicated in this report.

The work is not finished but is constantly going on. There are many problems yet unsolved, mostly because of time and the availability of trained workers. Four procedures not otherwise illustrated are (1) head tilt, (2) abdominal protuberancy, (3) hip thrust forward, (4) hyperextended knees, and (5) body lean. These are shown in Illus. V. The conformateur is shown in Illus. VI.

CONCLUSIONS

1. The results of this study are encouraging to the measurement procedures as applied to posture. The objective measurement schemes have been shown to be more precise than the subjective inspectional method according to the following approximate schedule:

Head and neck	three times as good on reliability. three times as good on objectivity.
Chest and abdomen	twice as good on reliability. four times as good on objectivity.
Shoulders	five times as good on reliability. thirteen times as good on objectivity.
Spine	twice as good on reliability. fifteen times as good on objectivity.
Feet	four times as good on reliability. four times as good on objectivity.

2. The subjective inspectional scheme, as carried out by three trained and experienced examiners who had worked intimately with each other for at least three years, gave results only 13.4 per cent better than pure chance guesses as an average in ranking pupils. The objective measurement scheme is as a whole four times as good, raising the mean correlations from .51 to .88 with a predictive index of .45 for the latter or 45 per cent better than chance.

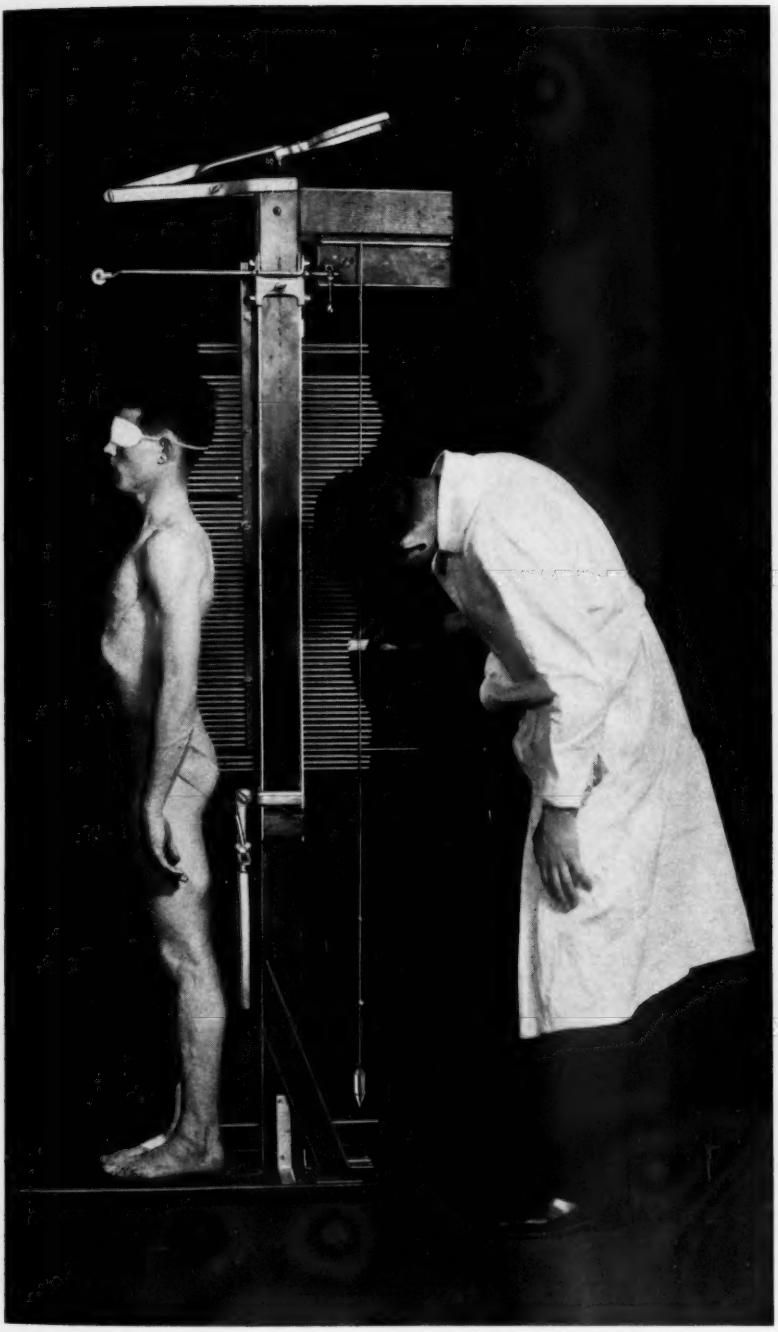
3. Objective measurements of each aspect of posture need to be separately made, using the best known instruments and techniques, and preserved along with all other measurements of health, physique, or sport ability. This will make possible the completion of a sorely needed series of studies to interpret fully the meaning of each aspect of posture in the light of these criteria. Almost no careful work has been done with full resort to statistical method to interpret the results. We are still depending upon "clinical opinion."

4. An entirely different philosophy and policy is needed by orthopedic and corrective workers as well as leaders of fundamental body mechanics workers to recognize the value of the measurement procedure (1) for pupil motivation, (2) individual contact and record of each pupil, (3) more careful and thorough diagnosis procedure, (4) to secure data for the building of group norms and grading scales on an acceptable statistical basis, and (5) to secure data which will be useful in further interpreting the significance of any particular element of posture. These needs warrant the allotment of more time and the appropriation of more money for equipment and also leaders trained in measurement.

5. That this study corroborates the findings of Franzen that subjective judgments of the type made on posture and nutrition are in a fair percentage of the cases unreliable enough to throw considerable doubt on their usefulness. Franzen is quoted as follows:

> "Judgments which set in motion expensive corrective procedures in the school should certainly be made in such a way that the resulting distinctions between children are not an accident of the physician who happens to make the judgments. . . . Any two physicians may agree or may not agree, depending upon their training, their beliefs, and the diagnostic emphasis which they give to the various aspects of their judgment."[15]

[15] Raymond Franzen, *op. cit.*



ILLUS. VI.—The Cureton-Gunby conformateur apparatus for measuring the spinal curves.

The Center of Gravity of the Human Body in the Antero-Posterior Plane and Its Relation to Posture,[1] Physical Fitness, and Athletic Ability

By Thomas Kirk Cureton, Jr.,
Professor of Applied Physics and Body Mechanics,
and
J. Stuart Wickens,
Instructor in Applied Physics and Body Mechanics,
Springfield College, Springfield, Mass.

INTRODUCTION

Need for Test.—There is a great need for accurate, consistent,[2] and valid body mechanics tests. The White House Conference on Child Health and Protection,[3] 1932, recommended:

"That body mechanics should be made the basic principle of all physical education . . . that body mechanics should be considered a major course in physical education schools."

One of the major problems in this field is the measurement of what one might call good body mechanics, objectively, without undue dependence upon inconsistent subjective judgments.

An item of major interest has been the examination of *how a person stands* because it has long been the belief that standing posture is an index to the state of health. *This paper reports the results of an effort on the part of its authors to develop a test which may be useful as a test of condition as reflected through posture.* In this case, the testing of the center of gravity in the antero-posterior plane was chosen because of the great number of times that references were encountered in the literature indicating that an analysis of posture in the upright position should begin with a consideration of the center of gravity.

Laws of Mechanics.—The body is enabled to stand upright because, first of all, the mechanical laws of equilibrium are satisfied. The center of gravity (the theoretical point which represents the center of weight)

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[1] Apparatus demonstrated at the American Physical Education Association Convention, Cleveland, Ohio, April 20, 1934, Administration of Tests and Measurements Section.

[2] "Consistent" means both reliable and objective.

[3] R. B. Osgood, *Body Mechanics, Education and Practice*, p. 42. New York: Century Company, 1932.

is located above the base, its vertical projection downward falling within the geometrical area of the base. In all problems of mechanics, it is customary to treat the body acting as a whole from its center of gravity. A body is more stable when its center of gravity is relatively lower and is balanced over the geometrical center of the area of the base. It maintains its balance with less effort under these conditions.

Historical Survey.—This study was preceded by an extensive investigation into the literature relating to the center of gravity. Many investigators have tested the location of the center of gravity in the horizontal plane (head to foot), and locate it approximately at the level of the umbilicus in men or 57/100 of the height from the feet to the head.[4] *No quantitative studies have been found which relate the center of gravity to the area of the base as a diagnostic test of posture.* The "gravity line," however, is frequently referred to in posture and corrective gymnastic books; its significance as indicating the stance and alignment of the body being repeatedly inferred. Reynolds and Lovett[5] appear to be the only workers who have experimentally investigated the problem. They devised a method for determining the center of gravity in the erect position and were studying its relationship to the spinal curves by means of a conformateur. This work was not completed due to the death of Lovett. No norms were established and the validity and precision of the method was not published. The scheme was based upon the *moments about one end* principle. (See Plate I–A.) Lovett recognized the basic relationship of the center of gravity to posture as indicated by this quotation:

> "It is evident that any reliable method of analysis must take into account the base of support and the line of gravity in order to correctly represent the normal standing position as seen from the side." 2nd. ed. *Lateral Curvature of the Spine and Round Shoulders*, 1912, pp. 172–173.

Amar[6] gives an approximate analysis of the significance of the gravity line as related to posture. The illustrations *B* and *C* (Plate I) show the antero-posterior gravity line approximately as the body is viewed in the profile plane. Illustration *B* shows the body in the erect position (military attention) as contrasted with the normal and easier position *C*. No quantitative analysis has been found as a basis for these drawings. Amar calls attention to the fact that the gravity line is located more posteriorly, passing through the external malleoli, with the body standing at military attention; and that the line moves forward when the body stands with relatively greater relaxation. *The*

[4] No attempt is made to quote all of this literature. Weber (1836) gives 56.7 per cent of the height from the feet, Meyer (1853) gives 59.5 per cent, Harless (1857) gives 57.99 per cent, and Braune and Fischer (1890) give 54.8 per cent.

[5] E. Reynolds and R. W. Lovett, "Method of Determining the Position of the Center of Gravity in Its Relation to Certain Bony Landmarks in the Erect Position," *Amer. Journal of Physiology* (May 1, 1909); *Journal Amer. Medical Assn.* (Mar. 26, 1910).

[6] J. Amar, *The Human Motor*, pp. 334–335. New York: E. P. Dutton & Co., 1920.

present study by the writers gives opposite conclusions. Of great interest is the observation of Zuntz and Katzenstein[7] that position *B* may require as much as 22 per cent more energy than position *C*, based upon oxygen consumption studies.

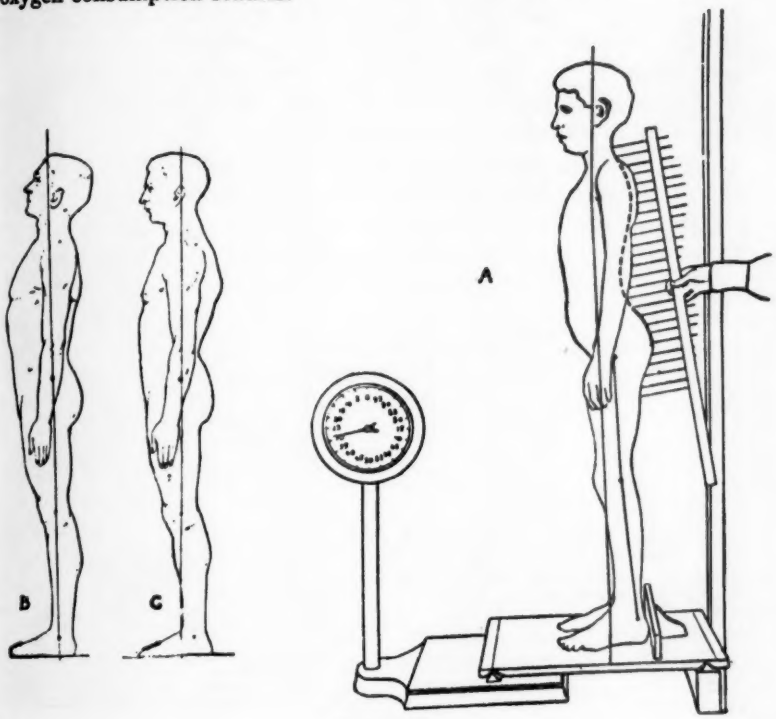


PLATE I

Illustration from J. Amar, *The Human Motor*, p. 335. New York: E. P. Dutton & Co., 1920.

Reynolds and Lovett Apparatus—2nd ed. *Lateral Curvature of the Spine and Round Shoulders*, pp. 172–175. Philadelphia: P. Blakiston's Son & Co., 1912.

The *gravity line* is the theoretical line erected vertically through the center of gravity. It is usually drawn in the profile plane. The literature contains frequent references to this line but again the writers have not been able to locate any quantitative studies which would show the exact method of measurement, norms for different age groups or body types, or significant research to interpret the meaning of the line. (See Plate II, Illustrations D and E.) Certain relationships which would appear to be true from reasoning upon the problem are mentioned in the literature. A few of these are quoted.

[7] Zuntz and Katzenstein, *Pfluger's Arch.*, vol. xlix, p. 361, 1891 (quoted from Amar, *op. cit.*, p. 338).

"The line through the skeleton figure shows center of gravity of body weight. If feet are not properly supported at this point they 'roll in'—cramping nerves and muscles—even arthritis may result.

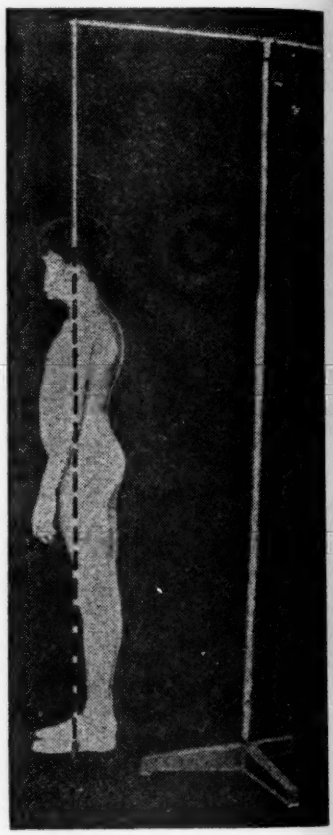
"The Health Spot is placed in every FOOT-so-PORT Shoe at this vital point."

HEALTH SPOT TRADE MARK MUSEBECK Copyrighted

E

Approximate center of gravity line in popular use. ILLUS. E

Right. — Illustration from Phelps and Kiphuth, *Diagnosis and Treatment of Postural Defects*, p. 21.



D

PLATE II

Phelps and Kiphuth[8] (Illustration D—Plate II) show the location of the gravity line by guess, the subject being asked to stand behind a vertical line to which is attached a plumb bob. The new book by these authors gives considerable discussion of the gravity line but no method of measuring it, or norms for rating persons. These writers state:

"The line of gravity from the mastoid falls slightly ahead of the ankle joint... the line of gravity of the body in the erect position passes anterior to the center of motion of the knee joint and thus there is a small component of the force of gravity acting in the direction of extension which aids in keeping the knee extended without muscle action . . . it passes between the two scaphoid bones and not directly through the tibio-astragalar joints."

[8] W. M. Phelps, and R. J. H. Kiphuth, *The Diagnosis and Treatment of Postural Defects*, p. 20, pp. 45–101. Baltimore: C. C. Thomas, 1932.

Amar[9] gives an analysis of this body mechanics problem, treating it quantitatively, but presumes conditions of balance which do not occur as a rule in the subjects experimented with in this report.

Investigation of the Gravity Line at Springfield.—The antero-posterior test, as described in this paper, was devised by Cureton in connection with laboratory work in applied physics. It was theoretically developed by using the standard center of gravity principles from physics. The test was diagrammed and explained to Wickens, who investigated it as a project topic in the Applied Physics II course, at Springfield College. In this project[10] he compared the convenience and precision of the *double-end under-support* method with the *see-saw, suspension,* and the *scale-at-one-end under-support* methods. The latter was previously mentioned as having been used by Reynolds and Lovett. Wickens concluded this 1932 project with the following statement:

"Cureton's method appears to be the most practical and most accurate procedure to follow. The average deviation (of the center of gravity measurement) in a series of nine trials repeated on the same individual was .186 inches . . . None (of the other methods) are as practical as Cureton's method."

In continued work, the project was the basis of a Master's thesis in physical education which was completed by Wickens[11] in June, 1934. This work proceeded under the guidance of Cureton. A group of 242 students, male physical education majors, was tested. The location of the antero-posterior gravity line was accurately determined on these men.

The possession of a large number of other postural and physical fitness test data on the same men has made a number of intercorrelations possible between the center of gravity and these items.

THE ANTERO-POSTERIOR CENTER OF GRAVITY TEST

Procedure.—

1. The subject is asked to step upon the balance board (*a-b*) and face in the direction of the length of the board. The internal malleoli are lined up even with the vertical pin (*c*) which is located in the exact center of the board. The board is supported at both ends from the center of each scale. (See Plate III, next page.)

2. The subject is instructed to stand in a normal postural position without stiffness and to maintain balance as perfectly as possible, and to continue to look straight ahead throughout the test.

3. The examiner balances the scales, first the forward one and then the rear scale, until both scales have their lever arms swinging freely between the guide stops. The subject is then told that he may step down from the balance board. The scales are read and both readings recorded. One-half of the weight of the board is deducted from each reading.

[9] Jules Amar, *op. cit.*, pp. 334–340.

[10] J. S. Wickens, "Comparison of the Various Methods of Determining the Center of Gravity," project in applied physics, 1932, Springfield College.

[11] J. S. Wickens, "The Center of Gravity of the Human Body in the Antero-Posterior Plane and Its Relation to Posture," Master's thesis, 1934, Springfield, Mass.

4. The calculation is made, preferably on a slide rule, or the reading taken from a prepared table (see chart). The result shows exactly how far the center of gravity is being balanced in front of the internal malleoli.

5. The absolute center of gravity result is converted into a percentile score by means of a normal curve chart or scale.

NOTE: Needless to say, it is wise to have the scales calibrated for accuracy and carefully adjusted to zero before beginning any series of weighings.

The test should take approximately one minute per subject and an additional one or two minutes for the calculation of the final result. Plate III shows the subject in position and the examiner balancing the scales. The postural measurements are more completely described in another article.[12]

Precision of the Test.—The test as it has been previously described has been thoroughly investigated with respect to the precision with which it can be administered. It should be noted, however, that the subjects which formed the basis for these studies were all male college students.

Measurements repeated by the same examiner (reliability) or repeated by different examiners (objectivity) gave the following results:

Data	Time Interval Between Tests	Reliability coefficient (same examiner)	Objectivity coefficient (several examiners)
69 freshmen class of 1938	2 minutes—subjects stepped off board between tests and balance beam riders shifted	$r = .90 \pm .015$	$r = .854 \pm .022$ (4 student examiners)
74 seniors class of 1934	2 minutes—subjects stepped off board between tests and balance beam riders shifted	$r = .928 \pm .015$	$r = .91 \pm .015$ (2 expert examiners)
30 sophomores class of 1936	2 minutes—subjects stepped off board between tests and balance beam riders shifted	$r = .90 \pm .02$	$r = .88 \pm .02$ (2 examiners, one expert and one student)
60 seniors class of 1935	3 months—1 set in October. Average of 2 sets in December	$r = .429 \pm .080$ NOTE: The reason for this drop was that many of these subjects were taught to stand differently. Some changed their stance and some did not. Some improved more than others in strength condition.	$r = .453 \pm .063$

The above correlations indicate a very satisfactory degree of precision for the test. In fact, it is among the best of any known tests on human subjects.

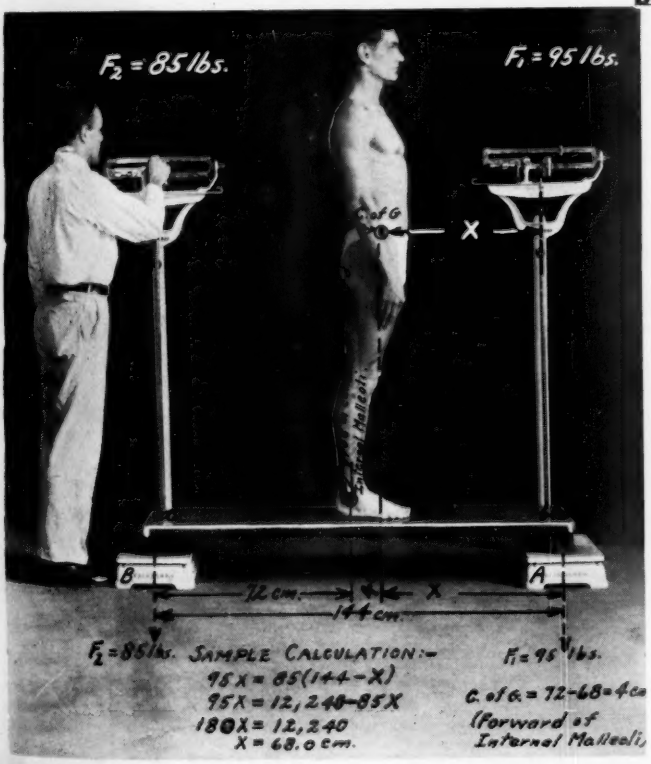
[12] T. K. Cureton, Jr., J. S. Wickens, and H. P. Elder, "Reliability and Objectivity of the Springfield Postural Measurements," pp. 81-92, this SUPPLEMENT.

	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90
60	0	.6	.12	1.8	2.4	2.9	3.4	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.4	9.8	10.3	10.7	11.1								
61	-.6	0	.6	1.1	1.7	2.3	2.8	3.4	3.9	4.4	5.0	5.5	6.0	6.4	7.0	7.4	7.8	8.4	8.8	9.3	9.7	10.2	10.6	11.0							
62	-1.2	-.5	0	.6	1.2	1.7	2.3	2.8	3.3	3.9	4.4	4.9	5.4	5.9	6.4	6.8	7.3	7.8	8.3	8.7	9.2	9.6	10.1	10.5	10.9	11.3					
63	-1.7	-1.1	-.7	0	.6	1.1	1.7	2.2	2.8	3.3	3.8	4.3	4.8	5.3	5.8	6.3	6.8	7.2	7.7	8.1	8.6	9.0	9.5	9.9	10.3	10.7	11.1				
64	2.3	-1.7	-1.1	-.5	0	.6	1.1	1.6	2.2	2.7	3.2	3.7	4.3	4.7	5.2	5.7	6.2	6.6	7.1	7.5	8.0	8.4	8.9	9.3	9.7	10.1	10.6	11.0			
65	-2.9	-2.3	-1.7	-1.1	-.6	0	.6	1.1	1.6	2.1	2.7	3.2	3.7	4.2	4.7	5.1	5.6	6.1	6.6	7.0	7.4	7.9	8.3	8.8	9.2	9.6	10.0	10.4	10.8	11.2	
66	-3.4	-2.8	-2.2	-1.7	-1.1	-.6	0	.6	1.1	1.6	2.1	2.6	3.1	3.6	4.1	4.6	5.1	5.5	6.0	6.5	6.9	7.3	7.8	8.2	8.7	9.1	9.5	9.9	10.3	10.7	11.1
67	-4.0	-3.4	-2.8	-2.2	-1.7	-1.1	-.5	0	.5	1.0	1.6	2.1	2.6	3.1	3.6	4.1	4.6	5.0	5.5	5.9	6.4	6.8	7.3	7.7	8.1	8.5	8.9	9.4	9.7	10.1	10.5
68		-3.9	-3.3	-2.7	-2.1	-1.6	-1.0	-.5	0	.5	1.1	1.6	2.1	2.6	3.0	3.5	4.0	4.5	5.0	5.4	5.8	6.3	6.8	7.2	7.6	8.0	8.4	8.9	9.2	9.7	10.1
69			-3.9	-3.3	-2.7	-2.2	-1.6	-1.1	-.5	0	.5	1.0	1.5	2.0	2.5	3.0	3.4	3.9	4.4	4.8	5.3	5.7	6.4	6.6	7.0	7.5	7.9	8.3	8.7	9.1	9.5
70				-3.8	-3.2	-2.7	-2.1	-1.6	-1.0	-.7	0	.5	1.0	1.5	2.0	2.5	3.0	3.4	3.9	4.3	4.8	5.2	5.7	6.1	6.5	6.9	7.3	7.8	8.2	8.5	9.0
	71				-3.7	-3.2	-2.6	-2.1	-1.5	-1.0	-.5	0	.5	1.0	1.5	2.0	2.5	2.9	3.4	3.8	4.3	4.8	5.2	5.6	6.1	6.5	6.9	7.3	7.7	8.1	8.5
		72				-3.6	-3.1	-2.5	-2.0	-1.5	-1.0	-.5	0	.5	1.0	1.5	1.9	2.4	2.9	3.3	3.8	4.2	4.7	5.1	5.5	6.0	6.4	6.8	7.2	7.6	8.0
			73				-3.6	-3.1	-2.6	-2.0	-1.5	-1.0	-.5	0	.5	1.0	1.4	1.9	2.4	2.8	3.3	3.7	4.2	4.6	5.0	5.5	5.9	6.3	6.7	7.1	7.5
				74				-3.6	-3.0	-2.5	-2.0	-1.5	-1.0	-.5	0	.5	1.0	1.5	1.9	2.3	2.8	3.3	3.7	4.1	4.6	5.0	5.4	5.8	6.3	6.7	7.1
					75				-3.5	-3.0	-2.5	-2.0	-1.5	-1.0	-.4	0	.5	1.0	1.4	1.9	2.4	2.8	3.2	3.7	4.1	4.5	4.9	5.3	5.7	6.1	6.5
						76				-3.5	-3.0	-2.4	-2.0	-1.6	-.9	-.5	0	.5	.9	1.4	1.9	2.3	2.7	3.2	3.6	4.0	4.4	4.8	5.3	5.7	6.1
							77				-3.4	-2.9	-2.4	-1.9	-1.4	-1.0	-.4	0	.5	.9	1.4	1.9	2.3	2.7	3.1	3.6	4.0	4.4	4.8	5.2	5.6
								78				-3.4	-2.9	-2.4	-1.9	-1.4	-.9	-.5	0	.5	.9	1.3	1.8	2.2	2.7	3.1	3.5	3.9	4.3	4.7	5.1
									79				-3.3	-2.8	-2.3	-1.8	-1.4	-.9	-.4	0	.5	.9	1.4	1.8	2.2	2.6	3.1	3.5	3.9	4.3	4.7
										80				-3.3	-2.8	-2.3	-1.8	-1.4	-.9	-.5	0	.5	.9	1.3	1.7	2.2	2.6	3.0	3.4	3.8	4.2
											81				-3.2	-2.7	-2.3	-1.8	-1.3	-.9	-.4	0	.5	.9	1.3	1.7	2.1	2.6	3.0	3.4	3.8
												82				-3.2	-2.7	-2.2	-1.8	-1.3	-.9	-.4	0	.4	.9	1.3	1.7	2.2	2.6	3.0	3.5
													83				-3.2	-2.7	-2.2	-1.8	-1.3	-.9	-.4	0	.4	.9	1.3	1.7	2.1	2.5	2.9
														84				-3.1	-2.7	-2.2	-1.8	-1.3	-.9	-.5	0	.4	.8	1.2	1.7	2.0	2.4
															85				-3.1	-2.6	-2.2	-1.7	-1.3	-.8	-.4	0	.5	.9	1.3	1.7	2.1
																86				-3.0	-2.6	-2.1	-1.7	-1.3	-.9	-.4	0	.4	.8	1.2	1.6
																	87				-3.0	-2.6	-2.2	-1.7	-1.3	-.9	-.4	0	.4	.8	1.2
																		88				-3.0	-2.5	-2.1	-1.6	-1.2	-.8	-.4	0	.5	.9
																			89				-3.0	-2.5	-2.1	-1.6	-1.2	-.8	-.4	0	.4
																				90				-2.9	-2.5	-2.1	-1.6	-1.2	-.8	-.4	0
																					91				-2.9	-2.5	-2.0	-1.6	-1.2	-.8	-.4
																						92				-2.9	-2.4	-2.0	-1.6	-1.2	-.8
																							93				-2.8	-2.4	-2.0	-1.6	-1.2
																								94				-2.8	-2.4	-2.0	-1.6
																									95				-2.7	-2.3	-2.0
																										96				-2.7	-2.3
																											97				-2.7
																												98			
																													99		
																														100	

NOTE:
Deduct one-half the weight of the board from each scale reading before looking up the value of the c. of g. or making any calculations. It is necessary that each half of the board be the same length and weight. See that the scales balance at zero before placing board on and that both scales read the same after the board is in position. The board should be steady.

WEIGHT

SCALE READINGS



PROCEDURE:

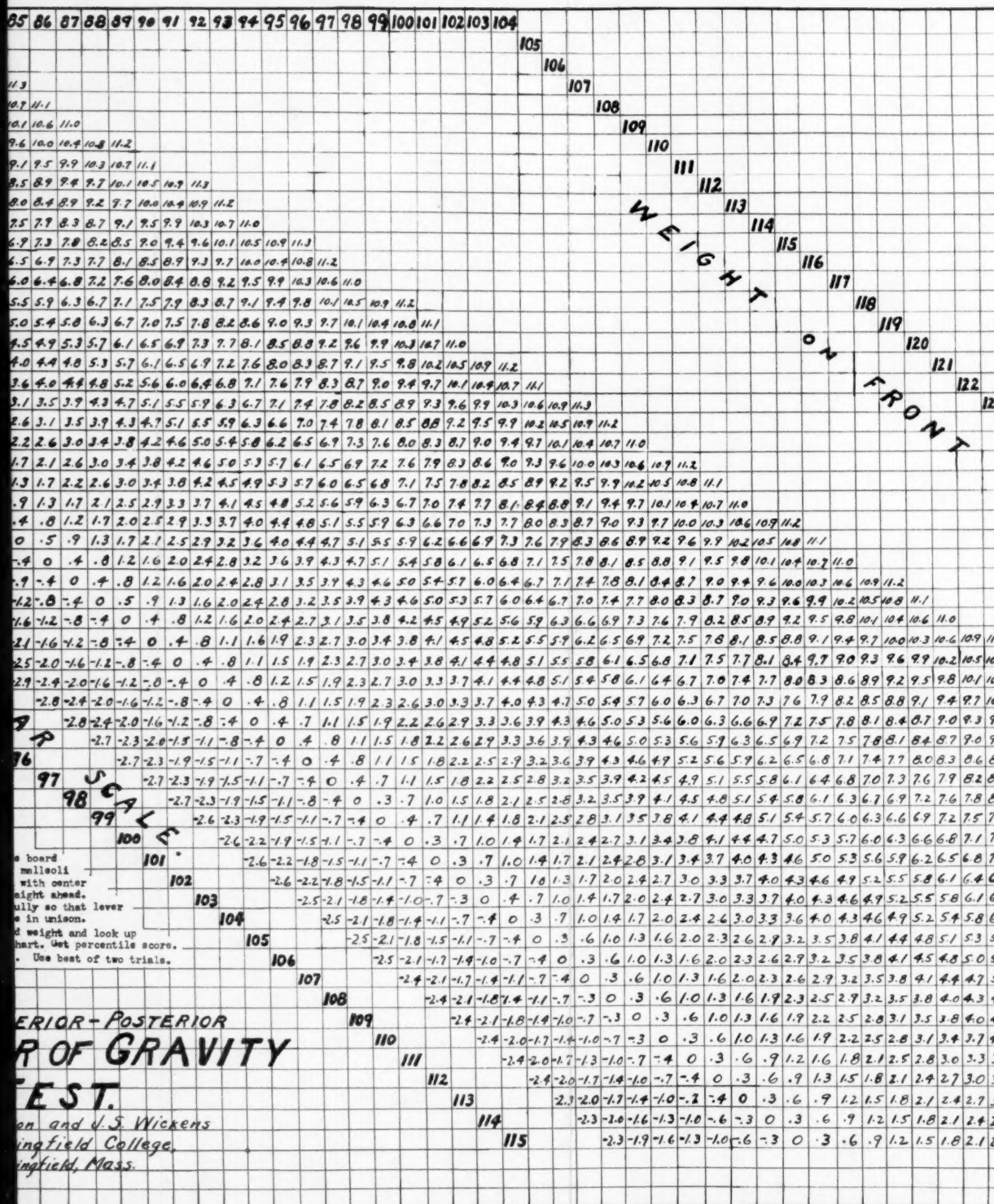
1. Place the subject on the board with internal malleoli lined up even with center pins, eyes straight ahead.
2. Weigh carefully so that lever arms fluctuate in unison.
3. Deduct board weight and look up c. of g. on chart. Get percentile sco
4. Repeat test. Use best of two trial

ANTERIOR-POST

CENTER OF GR

TEST.

T. K. Cureton and J. S. Wi
Springfield Colleg
Springfield, Mass.


WEIGHT ON FRONT
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ully so that lever
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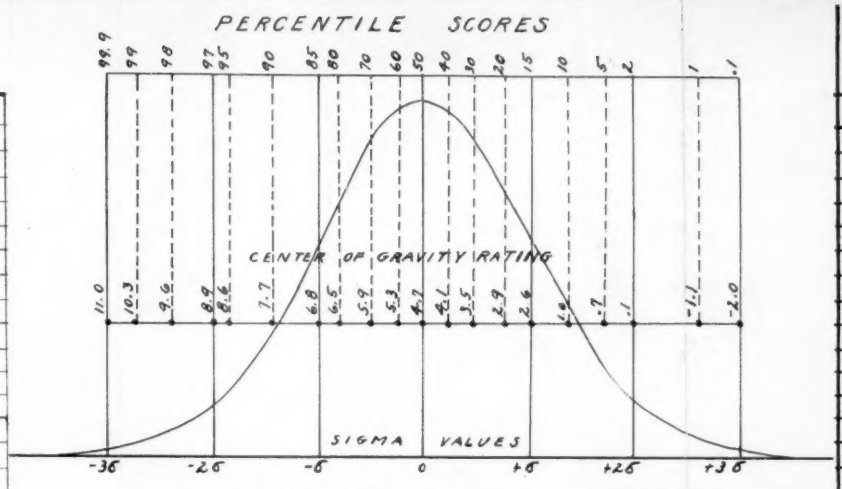
ingfield College,
ingfield, Mass.



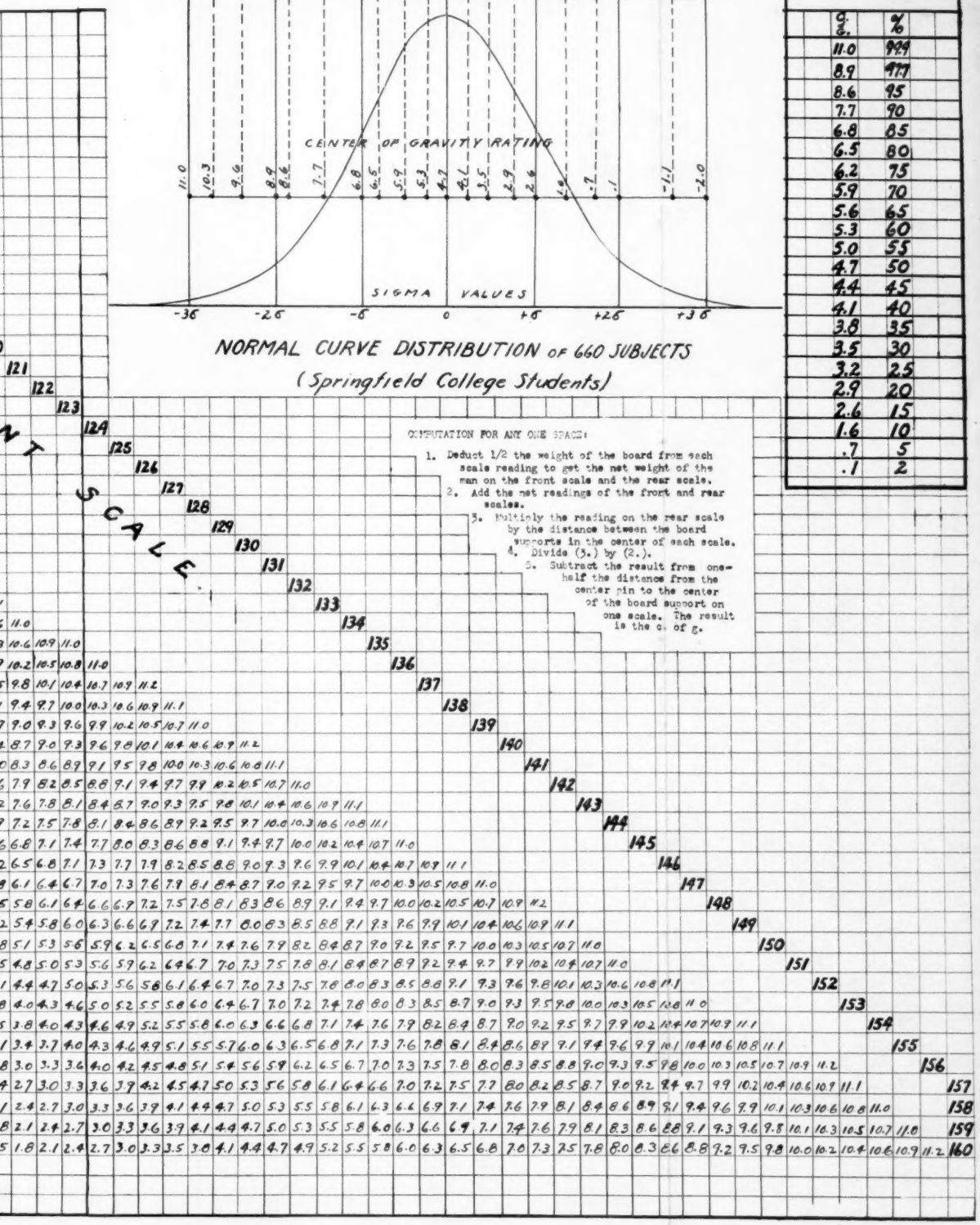
NORMAL CURVE DISTRIBUTION OF 660 SUBJECTS
(Springfield College Students)

PERCENTILE RATING SCALE.	
C. G.	%
11.0	99.9
8.9	97.7
8.6	95
7.7	90
6.8	85
6.5	80
6.2	75
5.9	70
5.6	65
5.3	60
5.0	55
4.7	50
4.4	45
4.1	40
3.8	35
3.5	30
3.2	25
2.9	20
2.6	15
1.6	10
.7	5
.1	2

COMPUTATION FOR ANY ONE SPACE:

1. Deduct 1/2 the weight of the board from each scale reading to get the net weight of the man on the front scale and the rear scale.
2. Add the net readings of the front and rear scales.
3. Multiply the reading on the rear scale by the distance between the board supports in the center of each scale.
4. Divide (3.) by (2.).
5. Subtract the result from one-half the distance from the center pin to the center of the board support on one scale. The result is the C. of G.

SCALE



EVIDENCE FOR INTERPRETATION OF THE TEST.—In order to determine the significance of the Test, it was correlated with a relatively

EVIDENCE FOR INTERPRETATION OF THE TEST.—In order to determine the significance of the Test, it was correlated with a relatively large number of measurements of posture, physical fitness, organic condition, and athletic ability. A table of these correlations follows:

Item Correlated with center of gravity	Uncorrected for Attenuation	Corrected for Attenuation	Subjects (Class)	Number of cases	Note on Measurement
Postural Items:					
1. Body Lean	$r = .864 \pm .02$		1936	121	Angle between a vertical line through the internal malleoli and a line from the latter point through the 7th cervical.
2. Lordosis	$r = .096 \pm .067$		1936	92	Average of 2 sets measured across specific arc by scaling conformateur rods on silhouettes.
3. Lordosis	$r = +.09 \pm .001$		1936	122	Lordosis measured to plumb bob string through 7th cervical point.
4. Lordosis	$r = +.022 \pm .052$		1938	168	Lordosis measured in true size on conformateur rods across specific arc, i.e., inflection to inflection of curve.
5. Kyphosis	$r = -.437 \pm .052$	$-.602 \pm .052$	1936	94	Average of measurements by two examiners from silhouettes made across specific arc.
6. Kyphosis	$r = -.21 \pm .06$	$-.29 \pm .06$	1936	112	Average of measurements by two examiners from silhouettes made across specific arc.
7. Kyphosis	$r = -.227 \pm .059$	$-.313 \pm .06$	1936	115	Kyphosis scaled from silhouettes by one examiner.
8. Kyphosis	$r = -.148 \pm .029$	$-.204 \pm .03$	1938	167	Measured on conformateur rods directly in true size.
9. Poke Neck	$r = .0009 \pm .08$		Seniors 1935	68	Measured by angle scaled on silhouettes between horizontal line through 7th cervical and line through 7th cervical and tragus of the ear. Men were checked to see that they looked straight ahead throughout the test.

Item Correlated with center of gravity	Uncorrected for Attenuation	Corrected for Attenuation	Subjects (Class)	Number of cases	Note on Measurement
10. Head Thrust Forward	$r = .30 \pm .07$	$.476 \pm .07$	1936	67	Horizontal distance between vertical lines through the 7th cervical and tragus of the ear.
11. Longitudinal Arches of feet	$r = -.171 \pm .092$	$-.186 \pm .092$	1937	50	Vertical height of arches taken by sandbox method. (see Validity of Footprint article.)
12. Longitudinal Arches of feet	$r = -.083 \pm .095$	$-.092 \pm .095$	1937	50	Arch angle (Clarke's method) taken from pedograph prints.
13. Longitudinal Arches of feet	$r = -.123 \pm .08$	$-.137 \pm .08$	1935	61	Arch angle (Clarke's method) taken from pedograph prints.
14. Big Toe Angle	$r = -.32 \pm .071$		1935	62	Angle between line through length of big toe and Meyer's line.
15. Chest Posture	$r = -.13 \pm .08$		1936	175	Kellogg's Ratio used.
16. Hip Thrust Forward	$r = -.022 \pm .08$		1936	115	Angle between vertical line through internal malleoli and line from same base point through greater trochanter.
Strength and Physical Fitness:					
17. Rogers P.F.I.	$r = .429 \pm .065$	$.505 \pm .065$	1936	77	Standard Test—see literature by Rogers.
18. Rogers P.F.I.	$r = .26 \pm .073$	$.312 \pm .073$	1938	64	Some data used which was taken 3 months apart and averaged. Result was to lower the correlation.
19. Rogers P.F.I.	$r = .342 \pm .067$	$.403 \pm .067$	1938	64	Average of two measurements repeated immediately.
20. Rogers P.F.I.	$r = .636 \pm .046$	$.75 \pm .046$	1938	64	Best of three trials on C. of G. and best of two tests on P.F.I.
21. Rogers P.F.I.	$r = .502 \pm .04$	$.59 \pm .04$	1936	101	Same man took all data.

22. Rogers S.I.	$r =$ .43 ± .056	.506 ± .056	1936	101	Same man took all data.
			Seniors		
23. Rogers S.I.	$r =$ .102 ± .105		1934	41	Seniors measured each other on strength tests.
			Seniors		
24. Rogers S.I.	$r =$ .43 ± .071	.506 ± .071	1934	49	Data retaken by Cureton and Wickens.
Organic Condition:					
25. McCurdy-Larson Endurance Condition Test:	$r = .06 \pm .08$		Freshmen 1938	87	Condition test given by Larson, McCurdy, Karpovich, Sargeant. See report by McCurdy and Larson in this Supplement.
Body Build:					
26. Davenport's Body Build Index: wt. (lbs.) × 1000/Ht² (in.)	$r = -.023 \pm .061$		1936	120	
27. Height	$r =$ .09 ± .06		1936	120	Standing height on stadiometer.
28. Weight	$r =$ .075 ± .06		1936	120	Weight on Fairbanks scales.
29. Abdominal Girth	$r =$ .092 ± .06		1936	120	At level of umbilicus.
30. Chest Girth	$r =$ .00 ± .06		1936	120	Taken one inch below nipples.
Athletic Ability:					
31. Sargent Vertical Jump	$r =$ .416 ± .057	$r = .490 \pm .057$	1937	112	Sargent jump taken by sighting head against a ruled cardboard.

$$\text{Condition Index} = -3.78\left(\begin{matrix}\text{Standing}\\ \text{Diastolic}\\ \text{Blood pressure}\end{matrix}\right) - 2.48\left(\begin{matrix}\text{Flarimeter}\\ \text{Breath Holding}\\ \text{after exercise}\end{matrix}\right) - 1.89\left(\begin{matrix}\text{Difference Horizontal}\\ \text{and Standing Dias-}\\ \text{tolic blood pressure}\end{matrix}\right) + 824.11$$

INTERPRETATIONS OF THE TEST

Relationships to Posture.—Most of all the test indicates how a person stands. This is borne out by the correlation of .864 ± .02 with body lean. It is obvious that leaning forward on the feet with the motion taking place in the ankle joints only would cause the center of gravity to move forward. It is interesting to note, however, that leaning forward this way causes the upper back to straighten, reducing the kyphosis. The correlation between body lean forward and kyphosis is — .363 ± .07. This is an important point from the standpoint of validating such a standing position as a good corrective exercise. This relationship forecasts the correlations between center of gravity and kyphosis. The correlations secured were — .437 ± .052, — .21 ± .06, — .227 ± .059, — .148 ± .029. These correlations are all significantly negative, indicating a definite trend for the men to have straighter upper backs who habitually stand with their weight more forward, *doing so naturally* without conscious effort or deliberate attempt to stand in an unnatural position.

It seemed at first that there was some correlation between poke neck and the center of gravity test. The correlation of .30 ± .07 was obtained in an early set of data in which some of the subjects lowered the head during the weighing. In later data obtained with better supervision of the head position, the correlation was .0009 ± .08. This is a defect in posture to which athletes are susceptible because in defense or attack it characterizes a better mechanical position to withstand a blow.

There is a slight indication that the men who stood with their center of gravity relatively more forward had lower arches as indicated by the negative correlations — .186 ± .092, — .123 ± .08 and — .092 ± .095. This is not a defect because it is proved in another study published herein that the stronger men have slightly flatter footprints.

The gross relationships of the center of gravity to posture have long been known (see Plate VI). The center of gravity in rigid military "attention" is farthest forward. In normal posture it is intermediate and with the body slouched in excessively poor posture it is farthest backward toward the heels. This is the usual situation as tested on men at Springfield.

Relationships to Strength and Physical Fitness.—Of outstanding importance are the correlations with the Rogers strength tests[18] (S.I.), .506 ± .056, .506 ± .071, and the Physical Fitness Index (P.F.I.) .75 ± .046, .59 ± .04, .505 ± .065. Men in better condition as indicated by these strength tests stand habitually with their weight carried relatively farther forward of the vertical line erected through the malleoli. This is a very interesting observation and gives an experi-

[18] F. R. Rogers, *Fundamental Administrative Measures in Physical Education*, Newton, Mass.: Pleiades Co., 1932.

C. of G.
C. of G.
C. of G.
C. of G.
Vertical line passes through center of gravity of the composite mass and is projected within the base of support.

PLATE VI

PLATE VI.—Posture influenced by carrying loads with corresponding change in the center of gravity as related to the base.

Illustrations from F. A. Schmidt, *Unser Korper*, pp. 61–66. Leipzig, 1903. Modified by the addition of the center of gravity and its vertical projection, approximately. Illustrations redrawn by permission E. P. Dutton & Co., N. Y. Included in the book *Training of the Body* by Schmidt and Miles.

mental basis for teaching the position of attentive erect posture in the gymnasium as one in which the body weight is thrust slightly forward. This position is a good static exercise for the plantar muscles on the sole of the foot, leaning forward causes them to contract and thereby grow stronger. The calf, hamstring, and quadriceps muscles also contract more. One method, then, of taking a mild corrective exercise for the feet and exercising the leg muscles is to lean slightly forward. Also, leaning slightly forward is a better position to step off from in gymnastic marching. Such a position may also be interpreted to be a better position for readiness to defend the body, to catch or stop objects coming toward the body. Men with stronger muscles seem to stand with greater lean forward without minding it. Others in poor condition, relatively, seem to stand with their center of gravity balanced more over the malleoli. Older persons with painful feet seem to attempt to rest their poorly conditioned foot muscles by leaning somewhat backward so that the heel bones carry a greater portion of the body weight. It is not surprising to note, therefore, the relatively high correlations with Rogers' strength tests in view of this reasoning.

The Rogers strength and physical fitness tests have been strongly validated as predictive devices for performance in power activities, i.e., those activities involving strength, such as running and jumping. They have been promoted with strong claims that they measure general organic health, physical fitness, and capacity for activity.[14]

The center of gravity test is a fairly good measure of the same qualities, whatever the Rogers test measures.

Relationship to Endurance Condition.—The McCurdy-Larson test of organic endurance condition is described in this issue of the Supplement. Correlation with the center of gravity test produced .06 ± 0.8. This seems to indicate that the kind of endurance measured by the organic endurance test is not muscular strength. In some other reports it has been claimed that strength is a measure of endurance. This remains to be proved.

Relationship to Body Build.—The center of gravity test is independent of body build. This is evidenced by zero correlations with Davenport's body-build index, height, weight, abdominal girth, and chest girth. There is no evidence to show that a person with a protuberant abdomen will stand with the center of gravity farther backward. This data is confined, however, mostly to young male adults.

Relationship to Athletic Ability.—The strong validation of the Sargent vertical jump by C. H. McCloy[15] as a measure of athletic ability suggested this test as a good one to represent athletic ability. The cor-

[14] F. R. Rogers, "The Significance of Strength Tests in Revealing Physical Condition," *Research Quarterly*, V:3 (Oct., 1934), 43–46.

[15] C. H. McCloy, "Recent Studies in the Sargent Jump," *Research Quarterly*, III: 2 (May, 1932), 236–242.

relation between the center of gravity test and the Sargent vertical jump was .490 ± .057, indicating that the men who stood with their center of gravity relatively more forward are better athletes.

CONCLUSIONS

1. A static center of gravity test has been developed which is definitely related to posture, strength, physical fitness, and athletic ability. This test is remarkably easy to administer, requiring about one minute per subject and satisfies the highest standards for precision as administered on college men.

2. The strength condition and aptitude for power capacity can roughly be determined for any subject from the center of gravity test.

3. The test is normed for college men.

4. How a person stands, i.e., leaning forward or backward from the ankle joints, is determined by this test splendidly.

5. Evidence is presented, believed to be the first, to show that men in better condition muscularly with better aptitude for athletics have flatter upper backs.

6. That a more forward position of the center of gravity is a better position for "readiness" in either attack or defense. It also indicates better muscular condition and athletic aptitude.

7. Men who stand better and who have better strength and athletic ability have a tendency to have slightly lower longitudinal arches of the feet as measured by footprints, probably due to muscular feet.

8. That muscular strength is not correlated with organic endurance condition, a quality probably more dependent upon the strength of the circulatory system, condition of the vessels, and blood, and by suppleness.

9. The center of gravity test is not influenced significantly by body build, i.e., the condition of the person and how he stands can be determined roughly without any corrections for body build.

10. That this simple center of gravity test opens up the way for many possible studies including:

a) The effect of high heel shoes on the carriage of body weight with relation to the base of support.

b) Typical weight balance of extremely fat persons, hunchbacks, pregnant women, old men bent with age, foot trouble cases, etc.

c) Norms for erect standing balance for all ages and both sexes.

d) The relationship between weight balance and foot defects.

A Test for Endurance in Speed Swimming

By Thomas Kirk Cureton, Jr.
Director of Aquatics and Coach of Swimming,
Springfield College, Springfield, Mass.

THE PROBLEM

Need of Endurance Test.—One of the major needs in coaching is to know the relative state of endurance condition of any swimmer at any particular time. The physiologist or medical examiner is able to determine such condition by means of the McCurdy-Larson condition test.[1] The fact that swimmers can be ranked in performance by measuring the pulse, blood pressure, and breath holding after exercise demonstrates that endurance in swimming is a circulatory phenomenon to a great extent. The writer came to the conclusion that endurance was the outstanding reason for the overwhelming victory of the Japanese men swimmers in 1932, at Los Angeles.[2] This conclusion was on the basis of circulatory tests, actual comparative tests of the strokes, and also the fact that every race won by the Japanese was won by more perfectly sustaining the pace. Since endurance is such a dominant factor in success, the coach needs a test to determine the status of his men in this quality. The average coach, however, will not give blood-pressure tests or any tests which require much time. The need is for a quick, reliable test which requires only a stop-watch, and which fits into the day's practice.

DEVELOPMENT OF THE ENDURANCE TEST

Observations on Champion Swimmers.—Since the Olympic games, careful observation of national championship contenders has shown that *ability* to *sustain* the pace always determines the winner. For instance, in observing Spence, Highland, and Lewis finish the 100-yard final in that order at Columbus, Ohio, 1934 N. C. A. A. championships, it was observed that the men finished in the order in which they could hold the pace in their second 50 yards:

Place	*Swimmer*	*Time 1st. 50*	*Time 2nd. 50*	*Drop off (secs.)*
1	Spence	25.0	27.4	2.4
2	Highland	24.6	28.4	3.8
3	Lewis	24.4	30.0	5.6

Drop-off times of poorer swimmers were always found to be greater.

In the 1935 N. C. A. A. Championships at Cambridge, the following splits were taken:

[1] Published in this research supplement.

[2] See articles by the writer, "Observations and Tests of Swimming at the 1932 Olympic Games," *Journal of Physical Education*, XXX: 7 (March, 1933), 125–130; "Factors Governing Success in Competitive Swimming," *N.C.A.A. Swimming Guide*, pp. 48–62. New York: Spalding Athletic Library, No. 91 R, Amer. Sports Pub. Co., 1934.

	Time on Laps				Total	Drop off
Swimmer	1	2	3	4	*Time*	(*sec.*)
Flachmann	11.6	13.6	13.4	14.2	52.6	2.6
Livingston	12.0	13.4	14.0	15.1	54.5	3.1
Jennings	11.8	14.2	14.6	15.8	56.4	4.0

In the above cases, Flachmann won the 100-yard championship, Livingston was second, and Jennings failed to qualify. The order of finish is in direct proportion to the ability of the swimmers to hold the pace.

Sampling Group for Statistical Study.—Observations of this kind led to a more careful study of the problem. Thirty-two cases from the Springfield College varsity squad were tested, taking time each lap and the final time, *but in these trials the swimmers were told to swim as fast as possible from start to finish and the start was in the water with a push from the wall allowed.*[3] In this sampling group it was found that the speed of the first lap correlated .87 with the final time and the drop-off index (cumulative slowing up, lap by lap in seconds) correlated .83. These two items were combined into a regression equation to predict total time with a multiple correlation coefficient of .963 ± 2.99 sec. This equation was:

$$\text{Time in 100 yards (60′ pool)} = 5.98\left(\begin{matrix}\text{Time of 60′ sprint}\\ \text{at top speed}\end{matrix}\right) + 2.88\left(\begin{matrix}\text{Drop-off}\\ \text{sec.}\end{matrix}\right) - 2.63$$

It seemed that this was a valuable approach and offered possibilities for differentiating between sprint speed (mostly due to power and efficient stroke mechanics) and endurance. The sixty-foot sprint time seemed to represent the former and the drop-off index the latter. Statistically determined, speed of the first lap determined 54.6 per cent of the performance and endurance 45.4 per cent of the total time as an average.

Study of Larger Group.—Next, one hundred cases were studied, including some varsity men but spreading the scale down into the poorer swimming groups. The statistical results on this group were as follows:

Range of group was 54 to 144 seconds in ability.
Mean ability for the 100-yard swim was 91.3 seconds.
Key: 1 = Time in the 100-yard dash (start in the water with push).
2 = Time to sprint 60 feet at top speed (start in the water with push).
3 = Endurance Index (slowing up in seconds computed cumulatively from lap to lap when the 100 yards is swum as hard as possible from start to finish).

$r12 = .73$ $\quad M1 = 91.3$ seconds.
$r13 = .55$ $\quad M2 = 13.25$ seconds.
$r23 = -.034$ $\quad M3 = 8.51$ seconds.
$r23.1 = -.74$

From these values the regression equation was constructed,

[3] It should be clearly understood that the author does not advocate that all 100-yard dashes should be swum this way. This is done to standardize the test as much as possible and to have the swimmer go his limit for as long as possible to insure that his endurance would be affected to a measurable degree.

Time in 100 Yards = 5 (*Time 60' Sprint*) +2.25 (*Endurance Index*) +5.5.

The multiple correlation for combining the speed test and the endurance test to predict the time in the 100-yard swim was:

$$R_{1(23)} = .912 \pm 3.28 \text{ seconds.}$$

Computing out the per cent contribution of each variable gave 57.3 per cent for speed and 42.7 per cent for endurance.

One of the most significant correlations is $r_{23} = -.034$, indicating that in the large group of medium to poor swimmers as the results actually were, speed and endurance were not significantly related to each other, the two qualities being different and required in almost equal proportions for success. A swimmer, poor in endurance, will have poorer time for 100 yards regardless of his speed for a short distance. Likewise, a swimmer poor in speed but with good endurance will also be handicapped. The ideal is to have high ratings in both factors.

The figures $r_{23.1} = -.74$ indicate that if the swimmers all swam the same time for the 100 yards, then faster pace would tire the swimmers more quickly and their drop-off indices would be greater, and vice versa.

It was found that very poor class swimmers had an endurance drop-off from 10 – 20 seconds, average class swimmers from 5 –10 seconds, the varsity squad candidates ranged from 3 – 6 seconds. The endurance drop-off was obviously a rough but effective classifying index. Best swimmers were relatively high in both speed and endurance.

It was soon obvious too, from studying the data collected on lap times, that there were several men on the squad who could break Weismuller's world's mark for the 100–yard dash if they could hold the pace of the first fifth of the race during the last four–fifths. For instance, one swimmer, Holland, could do the first length in 8.8. With no time lost for turns and perfect endurance his 100–yard time should be $8.8 \times 5 = 44.0$ sec. His actual time is 54.0 sec., a terrific discrepancy, a large part of which is just due to poor endurance as compared with that of world champions.

The prediction equation was used to differentiate between speed and endurance. Later, the test was normed so that a swimmer could tell on a 100 per cent scale what his rating was for both speed and endurance. This device was helpful to the coach. Tests, every two weeks, demonstrated that the endurance indices were improving steadily throughout the season. The better men were staying about the same in speed but the poorer swimmers were making improvements in mechanics, indicated by improved time on the first lap.

Test Throws Light on the Organic Requirement in Speed Swimming.—It has been shown that endurance has almost as much to do with good time in the 100–yard dash as stroke power. A good definition of perfect endurance is the ability to keep up an effort or speed exercise relatively long enough without slackening. In the 100–yard dash there would seem to be three major elements for success: (1) stroke propelling power, (2) endurance, and (3) ideal pace.

The drop-off index was correlated with the McCurdy-Larson index of endurance condition. The result was a correlation of .74 when corrected for attenuation in both tests. This correlation indicates that the kind of condition measured by the organic efficiency test is reflected directly in the swimming drop-off test to 33 per cent better than a chance relationship. (P. I. = .33.) This shows clearly that swimming a race as short as 100 yards requires considerable organic endurance to make good time. This quality of endurance is not *strength* because it does not correlate with strength. It is unquestionably determined by the characteristics of the circulatory system, i.e., force of the pump, condition of the tubes, and quality of the blood for carrying oxygen and neutralizing the acid fatigue products formed from muscular action. It is well known that tenseness, the lack of joint flexibility, and muscle suppleness hurt endurance. Other variables cannot effect the result very much because on the basis of the speed and the drop-off index alone 98 to 99 per cent of the time in the 100-yard dash can be accounted for. Strength is reflected in the speed test as is reaction time and will power. Likewise, internal resistance of muscle and joint friction is probably reflected in the endurance test. Certainly will power is reflected.

Reliability of the Test.—The short speed test has a reliability coefficient of .90 and the drop-off index a reliability coefficient of .77 as administered on two successive days.

Instructions for Giving the Test.—

1. Place the swimmer in the water, feet against the wall and holding on to the gutter with one hand, facing in the direction of the swim.

2. Instruct the swimmer to swim as *fast as possible* for 60 feet.

3. Start the swimmer with a sharp command or whistle and simultaneously start a stop-watch (double-hand preferred). Stop the watch when the swimmer has completed the 60-foot sprint.

4. Rest at least 15 minutes.

5. Instruct the swimmer to swim 100 yards by *doing the first lap as fast as possible* and then doing the best possible on the other laps. Have at hand his previous time for 60 feet at top speed so that if the time of the first lap is not within ½ sec. of the previous first lap time, the swimmer can be stopped and take the rest of the test when he *can* do the first lap as fast as possible.

6. Start the swimmer again and also the double-handed stop-watch. Time each lap of the swim and record the times.

7. Compute the time of each lap by deducting the first lap from the second, the second from the third, etc. Compute the drop-off index by deducting the time of the first lap from the second, the second from the third, the third from the fourth, and the fourth from the fifth. Add all of the differences cumulatively. An example follows:

Distance	*Cumulative Time (sec.)*	*Time per lap (sec.)*	*Drop-off (sec.)*
Time at 20 yds.	9.6	9.6	...
Time at 40 yds.	21.0	11.4	1.8
Time at 60 yds.	33.4	12.4	1.0
Time at 80 yds.	46.4	13.0	.6
Time at 100 yds.	59.2	12.8	.2
		Total.....	3.2 sec.

Note that the drop-off index can be secured by deducting the time of the first lap from the time of the last lap. However, the intermediate drop-off times are interesting for the swimmer to see. The times should gradually increase. If there is a negative result on any lap, it indicates that the swimmer paced the race and did not "go his limit." It is true that swimmers who do this will have a better endurance index than they deserve. They should be made to repeat the test.

NOTE: Proceed in a similar manner for the seventy-five-foot pool.

8. Look up both the speed and drop-off endurance ratings on the performance ladders (percentile charts) and give the swimmer a rating on each ladder. How many more rungs does he have to climb on the speed ladder? On the endurance ladder?

9. Instruct those who are relatively low in endurance or lower than their speed rating that they will have to train harder. Suggest what they may do in diet, pool dosage, stretching or relaxation drills.

10. Show that the time in the 100-yard swim can be computed very closely:

Method: (60-foot pool)

Multiply the time of the first lap $\times 5 =$ ($\times 4$ for 75′ pool)
Multiply the drop-off index $\times 2.25 =$ ($\times 2.6$ for 75′ pool)
Constant $= 5.5$
Add all = Calculated time.

11. Time the swimmer in a 100-yard swim his regular pace on another day and compare the result.

The scales for securing the percentile ratings are shown below. A copy of this should be put on the bulletin board, or better, a copy given to each swimmer on which his results can be directly checked.

PERFORMANCE LADDERS OF SPEED AND ENDURANCE IN THE 100-YARD CRAWL STROKE

Visualize that each column of figures is a ladder to be climbed to the world record in this event. How far up the speed ladder are you? How far up the endurance ladder are you? Notice that your time in the 100-yard swim is always in between your rating on speed and endurance.

Percentile Rating	Rungs to Climb	Time of Short Sprint (Start in water)		Endurance Index (1st lap from last)	Time in 100 yds.
		60 feet (sec.)	75 feet (sec.)	(sec.)	(sec.)
100	0	8.8	10.8	.5	49.7
99	1	9.0	11.0	1.0	51.9
98	2	9.4	11.4	1.1	54.1
97	3	9.6	11.6	1.2	55.7
96	4	9.8	11.8	1.3	57.4
95	5	10.0	12.0	1.6	59.0
94	6	10.1	12.1	2.0	60.7
93	7	10.3	12.3	2.3	62.3
92	8	10.5	12.5	2.6	63.9
91	9	10.7	12.7	3.0	65.6
90	10	10.9	12.9	3.3	67.3
88	12	11.0	13.0	3.5	68.5
86	14	11.1	13.1	3.8	69.6
84	16	11.2	13.2	4.1	70.2
82	18	11.3	13.3	4.4	71.3
80	20	11.4	13.4	4.7	72.5
78	22	11.5	13.5	4.8	73.4
76	24	11.6	13.6	5.0	74.0
74	26	11.65	13.65	5.2	74.8

Percentile Rating	Rungs to Climb	Time of Short Sprint (Start in water)		Endurance Index (1st lap from 5th) (sec.)	Time in 100 yds. (sec.)
		60 feet (sec.)	75 feet (sec.)		
72	28	11.7	13.7	5.4	75.7
70	30	11.75	13.75	5.6	76.5
68	32	11.8	13.8	5.8	77.4
66	34	11.9	13.9	6.0	78.3
64	36	12.0	14.0	6.2	79.2
62	38	12.1	14.1	6.3	80.2
60	40	12.2	14.2	6.5	81.1
58	42	12.3	14.3	6.7	81.9
56	44	12.35	14.35	6.9	82.5
54	46	12.4	14.4	7.1	83.4
52	48	12.5	14.5	7.2	84.2
50	50	12.6	14.6	7.4	84.9
48	52	12.7	14.7	7.6	85.9
46	54	12.8	14.8	7.7	86.7
44	56	12.9	14.9	7.9	87.8
42	58	13.1	15.1	8.0	88.7
40	60	13.2	15.2	8.1	89.7
38	62	13.3	15.3	8.3	90.4
36	64	13.35	15.35	8.4	91.1
34	66	13.4	15.4	8.5	91.7
32	68	13.5	15.5	8.7	92.4
30	70	13.6	15.6	8.8	93.1
28	72	13.8	15.8	9.0	94.7
26	74	14.0	16.0	9.2	96.2
24	76	14.2	16.2	9.4	97.6
22	78	14.3	16.3	9.7	98.9
20	80	14.4	16.4	10.0	100.2
18	82	14.7	16.7	10.4	102.2
16	84	15.0	17.0	10.7	104.3
14	86	15.2	17.2	11.0	106.4
12	88	15.5	17.5	11.4	108.4
10	90	15.7	17.7	11.7	110.5
5	95	17.3	19.3	15.1	126.3
0	100	19.3	21.3	18.6	143.9

CONCLUSIONS

1. A convenient endurance and power-mechanics (speed) test has been outlined.

2. The test is exceedingly useful for (1) motivation of the swimmer, (2) information about the swimmer as to the relative perfection of his speed and also his endurance condition, and (3) determining the amount of improvement which takes place during the season, or during any interval, in condition or in perfection of stroke.

3. For two years the men in the 100-yard dash at the N. C. A. A. Championships have finished in an order which was directly proportional to the degree to which they sustained the pace during the second half of the race.

4. A study of two groups enabled the relative per cent contribution

of speed and endurance to the final time in the 100–yard dash to be determined:

32 cases — Speed 54.6 per cent — Endurance 45.4 per cent
100 cases — Speed 57.3 per cent — Endurance 42.7 per cent

The first group had a larger proportion of better swimmers than the second.

5. In a large group of medium to poor swimmers the faster swimmers are not always the best in endurance or the poorest. This is a pure chance relationship as indicated by the correlation —.034 between speed and endurance.

6. A faster pace produces quicker fatigue in swimming as indicated by the partial correlation —.74 between speed and endurance with time in the 100 yards held constant.

7. Speed-swimming ability is governed very much by endurance from the lowest levels up because the drop-off endurance index begins at 20 seconds and gradually diminishes to 2 seconds as the swimmers approach championship ability.

8. Many swimmers have speed enough but not endurance enough to break a record, few are the other way, i.e., better in endurance than speed. Endurance improves more than speed for most men during the competitive season.

9. The swimming drop-off endurance index correlates .74 with the McCurdy-Larson organic endurance test. This is not a muscular strength condition but is mostly condition of the circulatory system.

10. The regression equation for predicting time in the 100–yard crawl swim in a 60-foot tank is: Time in 100 Yds. = 5 (Time 60-foot sprint) +2.25 (Drop-off Index) +5.5.

11. The reliability of the test has been determined as .90 for speed and .77 for endurance.

12. Exact instructions are included for giving the test.

13. The test is normed and percentile charts (performance ladders) are given for rating any swimmer.

14. The scales are also included for the 75–foot pool[4] but these are derived from the 60–foot pool data in part. They will be found to be satisfactory for all practical uses. The only present disadvantage is that the regression equation is only an approximate one, being
(Time 100 yds. 75–foot pool) = 4 (Time 75–foot sprint) + 2.6 (Drop-off Index) + 5.5

NOTE: The regression equation indicates the average situation as related to any set of data. There will be just as many swimmers who will "beat" the equation as they are who fail to live up to the equation. In any case the error is clearly defined. The regression equation should be interpreted as the law for the average type.

[4] The writer is indebted to S. C. Hazelton, Dartmouth College, for much of the seventy-five-foot pool data.

Undergraduate, Graduate, and Faculty Project Work in Applied Physical Science

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PROJECT WORK FOR "HONORS" STUDENTS

"*HONORS" Work at Springfield.*—There is a type of "honors" work going on at Springfield College for qualified juniors, seniors, and graduate students which deserves special mention. This is the *project*[1] work in applied physics, anthropometry, and body mechanics. It is open to those who are exceptional students in these subjects and who would like to receive some training in research methods, as well as contribute in some definite way to the vigorous research program being promoted in this field. The work is cooperative, with students working hand in hand with tutors, instructors, and professors for the solution of some definite problem. In this work the student is allowed to follow his "bent," interest being the motivating factor. Projects which culminate in a definite worth-while report are rewarded with *credit* of one, two, or seven (thesis) semester hours. Many of them, however, are done without credit on a pure interest basis. Here the better students have an outlet for their budding capability for initiative and original work.

Approach to Thesis Work.—Some of these projects grow into theses in graduate year. Some have been published. All that are worthy are permanently bound and kept for reference. The techniques employed are those of research, somewhat abbreviated of course, but including many fundamental ideas. Much of the guidance has been through individual conference. One seminar course "Research Methods in Physical Science" has been taught for the past five years into which the most capable and interested pupils enroll. The fall term is devoted to a review of the principles of mechanics, procedures in tests and measurements, and a survey of a large number of problems which need solution. During the winter term the pupil pursues the study with guidance in the form of group seminar discussions and individual conferences, but largely proceeds under his own initiative, with laboratory facilities available.

It is the distinct purpose of this work to awaken the *desire to know* within the student and to foster the opportunity for *creative* achieve-

[1] A large number of these permanently bound projects were exhibited at the National Convention, American Physical Education Association, Cleveland, Ohio, 1934.

ment. Every student has to be educated up to the point of wanting to tackle a formidable thesis. It is also certain that *some* of this inclination must be transferred during undergraduate years.

Mathematics and Physics.—Such work as this has always been hampered by the inadequate assortment of courses for the "scholar" in professional physical education colleges. Research work demands relatively more mathematics, particularly statistics, graphical methods and aspects of advanced algebra, trigonometry, analytical geometry, and calculus. Springfield has been developing mathematics courses under the leadership of Professor Hickox to fill this need. In many instances the mathematical problem is treated individually with each project by the writer, or discussed in seminar. Much of the older anthropometrical work has been discarded and in general has lost prestige in the eyes of those who see the mathematical discrepancies. It is certain that better training needs to be offered in this field.

Physics is fundamentally related to research. Physical problems are encountered at every turn in anthropometrical testing, in analyzing athletic skills, in probing the causes of physical defects or principles of good body mechanics, in hygiene problems, plant or field construction, and in all bio-physical problems. The writer has surveyed these relationships more intimately for readers who want more information.[2] Because of these intimate relationships the writer as physics teacher has grown naturally into the guidance of this work.

Studies on the Analysis and Design of Instruments Used in Physical Education.—There are many testing instruments being used in physical education work. Physical educators should know how precise these are, their mechanical principles, and wherein they may be improved. Of twenty projects in this field which are worthy of mention, four of these have been published, namely, the studies by Lyle Welser,[3] David E. Coe,[4] C. C. Yocum,[5] and J. S. Wickens.[6] Other studies of exceptional merit are the ones by Welser, "A Mechanical Analysis of the Narragansett Spirometer"; the study by H. P. Elder and Charles Silvia, "A Mechanical Analysis of the Flarimeter"; A. Nordstrom's study, "A Comparative Analysis of the Efficiency of Two Types of Stethoscopes";

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[2] T. K. Cureton, "Physics Applied to Physical Education," *Journal of Health and Physical Education*, III: 1 (Jan., 1932); also, *A Laboratory Manual Syllabus in Physics Applied to Physical Education*, and *Syllabus of Theory Lectures on Physics Applied to Physical Education*, planographed, Sept., 1933.

[3] Lyle Welser, "A Practical Electro-Mechanical Race Timer," *Research Quarterly*, IV: 4 (Dec., 1933). Welser has obtained a patent on this device.

[4] T. K. Cureton, and D. E. Coe, "An Analysis of the Errors in Stop-Watch Timing," *Research Quarterly*, IV: 2 (May, 1933). Associated Press dispatch to all papers, by Allan Gould, July 16, 1931.

[5] C. C. Yocum, "An Electric Flashboard for Diving Scores," *Beach and Pool* (March, 1934).

[6] T. K. Cureton, and J. S. Wickens, "The Center of Gravity in the Antero-Posterior Plane and Its Relationship to Posture, Strength, Physical Fitness, and Athletic Ability," this SUPPLEMENT, pp. 93-105.

and H. P. Elder's study, "A Mechanical and Kinesiological Analysis of the Springfield Postural Strength Testing Plinth." Some of these will probably be published in time. The completed studies in this group are listed as follows:

1. Burr, W. P., "An Analysis of the Short Static Postural Tests," 1932.
2. Burr, W. P., "A Mechanical Analysis of the Narragansett Spirometer," 1932.
3. Coe, D. E., "Analysis of the Nature and Magnitude of the Errors in Stop-Watch Timing," 1931.
4. Danielson, A. J., "The Effects of the Tissues of the Arm on the Measurement of Blood Pressure," 1933.
5. Elder, H. P., and Silvia, C. E., "A Mechanical Analysis of the Flarimeter as an Instrument for Measuring Vital Capacity," 1932.
6. Elder, H. P., "A Mechanical and Kinesiological Analysis of the Springfield Postural Strength Testing Plinth," 1934.
7. Heidloff, R. C., "Reliability of the Cureton-Gunby Conformateur-Silhouettograph Spinal Measurements," 1933.
8. LaRue, R. C., "A Method of Determining the Weight Thrust on the Foot in the Lateral Plane," 1933.
9. Marker, R. M., "Mechanics and Kinesiology of the Back and Leg Dynamometer Test," 1933.
10. Merkle, G. O., "The Hydroplane Principle in Swimming," 1933.
11. Murray, K., "Precision of the Franzen Skin Thickness Calipers," 1933.
12. Nordstrom, A., "A Comparative Analysis of the Efficiency of Two Types of Stethoscopes," 1933.
13. Saffer, R., "The Design of an Ankle Fleximeter," 1931.
14. Squires, J., "A Mechanical Pacer for Use in Practice Swimming," 1933.
15. Welser, L., "A Practical Electro-Mechanical Race Timer," 1932.
16. Welser, L., "A Mechanical Analysis of the Narragansett Spirometer," 1932.
17. Wickens, S., "A Comparison of Methods for Determining the Center of Gravity in Man in the Vertical Position," 1932.
18. Wilson, C. T., "A Mechanical Analysis of the Narragansett Spirometer," 1932.
19. Wilson, C. T., "An Analysis of the Short Static Postural Tests," 1932.
20. Yocum, C. C., "An Electric Flashboard for Diving Scores," 1933.

Athletic Skill Studies.—A large group of studies is accumulating in the field of athletic skills. New knowledge about swimming, track and field events, gymnastics, canoeing, diving, football, and athletic skill tests has been developed in more than twenty separate studies in this field. Ultimately, these facts will find themselves in the literature perused by coaches, and will become part of the theoretical material which students of physical education will study. The theoretical principles of athletic action, with stress on mechanics, are being developed. The literature has been strangely devoid of scientific work on sports. That this is a fertile and worth-while field is unquestioned. Such studies should be pushed ahead with great vigor.

Swimming.—There was published in the *National Collegiate Athletic Association Rulebook for Swimming and Diving*, 1934, a summary of thirteen studies made on swimming. Eight of these studies were

by Cureton,[7] and all have been published in the literature. Studies were also included as references in this article which were done by Dr. P. V. Karpovich,[8] a member of the faculty, Weitzdorfer,[9] Wilson,[10] and Merkle.[11] The studies by Karpovich were physics studies but done under his own leadership in the Physiology Department. Allen[12] completed a thesis on the frog kick in 1933. Cureton[13] has published several other articles and a book related to this phase of sport, all of which involve mechanics to some extent. The studies by Holmes and Baker,[14] and Lanoue,[15] are the newest contributions in this field.

Track and Field.—The track and field studies are now crystallizing into some summary reports. Cureton's series in the *Scholastic Coach* magazine are examples.[16] Other projects in this field which are unpublished are:

1. Burr, John H., "Methods of Studying the Track Racing Start," 1931.
2. Footrick, Wm., "Mechanics and Kinesiology of Javelin Throwing," 1935.
3. Knight, W., and Hepp, "Relationship of Strength and Flexibility to Speed in the Track Racing Start," 1935.
4. Memery, H. N., "Mechanics of the Projection Force in Shot Putting," 1935.
5. Miller, C. A., "A Mechanical Analysis of the Shotput," 1931.
6. Wetterling, E. P., "Norms for Track and Field Ability Among the Springfield Freshmen," project, 1932.

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[7] T. K. Cureton, "The Coaching of Swimming and Diving," *Swimming Pool World*, (March, 1932); (2) "Objective Tests of Swimming," Master's Thesis, Springfield College, 1930; (3) "The Stop-Watch Method for Testing the Efficiency of Speed Swimmers," *Beach and Pool Magazine*, (Feb., 1930); (4) "Mechanics of the Crawl Arm Stroke," *Beach and Pool Magazine*, (May, 1930); (5) "Relationship of Respiration to Speed Efficiency in Swimming," *Research Quarterly*, (March, 1930); (6) "Mechanics and Kinesiology of the Crawl Flutter Kick," *Research Quarterly* (Dec., 1930); (7) "Observations and Tests of Swimming at the 1932 Olympic Games," *Journal of Physical Education*, XXX: 7 (March, 1933); (8) *The Teaching of Elementary Swimming and Diving*, Mimeographed book, 1931.

[8] P. V. Karpovich, "Swimming Speed Analyzed," *Scientific American*, (March, 1930); also "Water Resistance in Swimming," *Research Quarterly*, (Oct., 1933).

[9] R. Weitzdorfer, "Static Slip in the Crawl Stroke," project, 1933.

[10] C. T. Wilson, "Coordination Tests of Swimming," Master's Thesis, 1933. Published in *Research Quarterly*, (Dec., 1934).

[11] G. O. Merkle, "The Hydroplane Principle in Swimming," project, 1933.

[12] Homer Allen, "Mechanics and Kinesiology of the Frog Kick as Used in the Breast Stroke," Master's Thesis, 1933. See *Beach and Pool Magazine*, (Oct., 1933).

[13] T. K. Cureton, "Natural and Artificial Buoyancy, Flotation and Body Balance in the Water," *Beach and Pool Magazine*, (Sept., 1933); "A Test for Endurance in Swimming," this SUPPLEMENT, pp. 106-112; *How to Teach Swimming and Diving*, Association Press, 1934.

[14] W. Holmes, and R. Baker, "Analysis of Swimming Turns," project, 1935.

[15] F. Lanoue, "Mechanics of Diving," (in process).

[16] T. K. Cureton, series on mechanics of track and field activities, *Scholastic Coach Magazine*, 1935; (1) "Mechanics of the Track Racing Start," (Jan., 1935); (2) "Mechanics of Track Running," (Feb., 1935); (3) "Mechanics of the Shot Put," (Mar., 1935); (4) "Mechanics of the High Jump," (April 1935); (5) "Mechanics of the Broad Jump," (May, 1935). The principles of (3), (4), and (5) were presented in a paper, Research Section, National Convention, American Physical Education Association, Cleveland, Ohio, April, 1934, "Mechanics of Projection Events in Track and Field." Another published article is "Measuring Air Resistance in Running," as told to T. R. Brinning, *Athletic Journal*, (Feb., 1931).

Gymnastics and Other Sports.—

1. Elder, H. P., and Holmes, W., "Vertical Height of the Sargent Jump from Time Observations," 1935.
2. Fowler, D., "Mechanics of Canoeing," 1935.
3. Harris, R., "Mechanical Analysis of the Up-Start," 1934.
4. Lambert, Q., "Relationship Between Various Sports and the Percentage of Failures in the Items of the Brace Motor Ability Test," 1932.
5. Seeley, J., "Mechanical Analysis of the Back Handspring," (in process).
6. Shields, J. A., "Mechanics of Football Punting," (in process).

Anthropometry and Body Mechanics Projects.—In connection with the anthropometry and body mechanics work offered to seniors there has been a large number of worth-while projects accruing. A few of the more worthy of these have grown into theses, including:

1. Gunby, W. E., "Physical Tests of Antero-Posterior Spinal Measurement," 1933.
2. Gipson, C. F., "The Effect of Exercise on the Antero-Posterior Posture of College Freshmen," 1933.
3. Gunkler, O., "Body Mechanics as Related to Intelligence, Scholastic, and Physical Education Grades," 1933.
4. Seitzer, P., "Accuracy and Reliability of the Postural Strength Tests," 1932.
5. Wickens, J. S., "The Center of Gravity in the Antero-Posterior Plane and Its Relationship to Posture," 1934.

There have been several published articles from studies in this field by Cureton,[17] Wickens,[17] and Elder.[17]

There are more projects by students in this field of work than can be mentioned in detail. The better of these have been collected and bound into three volumes:

Volume I — *Body Size and Type Studies as Related to Athletic Performance:*

1. Ainsworth, R. R., "Ratio of Chest Girth to Depth Related to the 50–Yard Dash."
2. Allen, G. L., "Correlation of Calf Girth with Time to Swim 100 Yards."
3. Cate, R. P., "Relation Between Body Type and Achievement in the 50–Yard Dash."
4. Chisholm, E. A., "Relation of Vital Capacity to the 50–Yard Dash."
5. Footrick, W., "A Statistical Analysis to Determine the Relationship of Physical Measurements to Efficiency in Baseball Throwing."
6. Gibbs, H. P., "Relation Between the Sub-Costal Angle and the Vital Capacity of 123 Members of the Class of 1936."
7. Graham, D. F., "Correlation of Body Types of the 1932 Springfield College Freshmen with Their Athletic Ability."
8. Hawkes, W. E., "Variations in Shot-Putting as Related to Height, Weight, Arm Span and Grip Strength."
9. Heald, C. H., "Abdominal and Chest Girth Relationship of the Springfield Freshmen."

[17] T. K. Cureton, "Validity of Antero-Posterior Spinal Measurement," *Research Quarterly*, II: 3 (Oct., 1931); "Validity of Footprints as a Measure of Vertical Height of the Arch and Functional Efficiency of the Foot" by T. K. Cureton, this SUPPLEMENT, pp. 70-80. "Reliability and Objectivity of the Springfield Postural Measurements," by T. K. Cureton, J. S. Wickens, and H. P. Elder, this SUPPLEMENT, pp. 81-92. "Center of Gravity in the Antero-Posterior Plane and Its Relationship to Posture, Physical Fitness, and Athletic Ability," by T. K. Cureton, Jr., and J. S. Wickens, this SUPPLEMENT, pp. 73-105.

10. Johnson, L. W., "The Correlation Between Neck Girth and Ability to Shot Put."
11. Locke, R. S., "Vital Capacity in Relation to Height and Weight."
12. Mear, F., "A Study of the Weight/Height Index."
13. Parker, A. H., "Correlation of Sitting and Standing Height."
14. Purdy, R. L., "Correlation Between Calf Girth and 440-Yard Dash."
15. Purrington, D. W., "A Correlation of Vital Capacity and Time Required to Run the 440-Yard Dash."
16. Quirk, W. R., "Baseball Throwing in Relation to Arm Span, Weight, Height, and Grip Strength of 116 Freshmen in Springfield College."
17. Rohr, A., "Correlation Between Vital Capacity and the 100-Yard Swimming Dash."
18. Sargent, Jr., B. P., "Ratio of Chest Depth / Chest Breadth and Ability in the 440-Yard Run."
19. Wells, C. G., "Relationships Between Arm Span, Sitting Height, Standing Height, Ratio of Arm Span / Height and Ratio of Bust / Height."
20. Wheeler, R. D., "Correlation Between Length of Legs and the Time Required to Run the 50-Yard and 440-Yard Dashes."
21. Wilson, C. T., "To Determine the Relationship Between Weight and Performance in the 100-Yard Free Style Swim."

Volume II — *Studies on Posture* (*Spinal Curves, Shoulders, Chest, Body Lean, and Feet*)

1. Boynton, J., "To Observe the Relationship of Vital Capacity to Chest Expansion and Normal Chest Girth."
2. Braga, O. S., "Distribution of Arch Depth of the Human Foot and the Big Toe Angle in Springfield College Freshmen," 1932.
3. Cranston, C. E., "Distribution of Arches in School Children," 1932.
4. Davis, C. W., "Vertical Height of the Arch by Sand-Box Impressions," 1933.
5. Eisold, A. G., "To Observe the Relationship of the Width and Length of the Foot to Running and Jumping," 1932.
6. Elder, H. P., "Correlations Between Neck Lordosis, Kyphosis, Lordosis, and Rogers Strength Index," 1934.
7. Engle, F. S., "Grading Kyphotic Curvature of the Freshman Class According to the Norm of the Class," 1932.
8. George, L., "Correlation Between Knee Posture and Flat Feet," 1932.
9. Jordan, F. A., "Distribution Curve of the Degree of Lumbar Curvature of the 1932-33 Freshmen," 1932.
10. LaRue, R. C., "A Method of Determining the Weight Thrust on the Foot in the Lateral Plane," 1932.
11. Marker, R. M., "Correlations Determined Between Thigh Flexor Strengths and Lumbar Curvature Measurements of the Spine," 1932.
12. Meyers, H. A., "The Correlation Between Neck Lordosis and the Thoracic Curve of the 1932-33 Freshmen," 1932.
13. Owens, J. D. "Relation of Spread of the Arch to Running the 440," 1932.
14. Pauff, G., "Body Lean As a Method of Checking Posture," 1932.
15. Rising, L. R., "The Distribution of Round Shoulders in the Freshman Class Entering Springfield College in the Fall of 1932," 1932.
16. Roberts, A. W., "The Relationship Between Kyphosis and Lordosis," 1932.
17. Rose, Jr., C. F., "Relation of Flat Feet to the 50-Yard Dash and Broad Jump," 1932.
18. Schemmerhorn, E. N., "The Correlation Between Round Shoulders and Shoulder Flexibility," 1932.
19. Shaw, P., "The Relationship Between Weight and Flat Feet in Boys," 1932.
20. Shay, E. L., "Historical Survey of the Antero-Posterior Spinal Measurement Methods," 1932.

21. Simons, H. R., "A Critical Study of the Feet, Their Ailments and Corrective Exercises," 1932.
22. Stanton, F. W., "To Determine Correlation Between Chest Expansion, Chest Carriage, Chest Size and Ability to Run the 50-yard Dash," 1932.
23. Todd, B. F., "Relation Between the Sub-costal Angle and Lift of the Chest," 1932.
24. Travis, A., "Correlation Between Size of the Calf Muscle and Flat Feet," 1932.
25. Vizely, K., "Trunk Size, Flexibility and Strength as Related to Vital Capacity," 1934.
26. Vizely, K., "The Shoulder Angle and Its Relation to Vital Capacity," 1933.
27. Warner, F. H., "Correlation Between the Chest Ratio and Kyphosis," 1933.

Volume III—*Strength, Flexibility and Motor Ability Studies.*

1. Anderson, G., "Rogers' Strength Test and Physical Fitness Index," 1932.
2. Connell, J. T., "A Chart and Scale of Flexibility Tests," 1932.
3. Ettline, K. L., "Correlation of Back Flexibility and Vital Capacity," 1932.
4. Fraser, D. C., "Correlation Between Hand Gripping Strength and Push-ups," 1932.
5. Hachadourian, A., "Relationship Between Chest and Abdominal Tensions and Speed in the Fifty-Yard Dash," 1932.
6. Knight, W. I., "Rogers' Strength Test Compared on the Freshmen and Senior Classes at Springfield College," 1935.
7. Rapuzzi, J. F., "Relation of the Freshmen Strengths in Comparison to Rogers' Standard," 1932.
8. Shay, C. T., "Back and Leg Strength in Relation to the Lumbar Curve as Measured on the Conformateur and as Scaled from Silhouettes," 1932.
9. Stone, D., "Relationship of Pelvic Flexibility to Athletics," 1932.
10. Vogt, H. G., "Norms for Flexibility Tests of the Ankle, Shoulder, Hip and Back," 1935.

General or Bio-Physical Projects:

1. Kelly, C. C., "Construction and Drainage of Athletic Fields," 1933.
2. Olsen, R. M., "Measurement of the Light in the Classrooms, Laboratories, Gymnasia, Library and Pool of the Springfield College," 1935.
3. Robinette, E. O., "Specific Heat of Therapeutic Materials," 1933.

CONCLUSIONS

1. Project work as "honors" work is a progressive step in education at Springfield College.

2. The data and reports being collected and preserved make a wealth of material available for future students.

3. The men themselves take pride in participation in some small but definite phase of this broad research program.

Heart Rate and Blood Pressure as Measures of Physical Condition During Adolescence

By Erastus W. Pennock, B.P.E., M.P.E.

THIS study was initiated with a view to determine a fair means by which indices of physical fitness in individuals might be measured. At the time of the writing of this thesis no generally accepted methods for measuring the degree of physical condition as found amongst youth were available. With this in mind and with a desire to either prove or disprove the fact that youths, with their ever active life, should be comparable in condition to adults, the writer at the suggestion of Dr. J. H. McCurdy chose as a test of measurement the Schneider Test, with some additional data explained later.

The subjects for this investigation were boys from the Buckingham Junior High School of Springfield, Massachusetts, grades 7, 8, and 9. They represent all social classes and include a large variety of social and racial mixtures. No attempt was made to study the various racial groups in relationship to this study. In all 282 boys were studied ranging in age from 10 to 17 years.

As the tests were conducted three times throughout the school year, in the fall, winter and spring, the increase in age distribution for the second and third test might remove a boy out of an age period below and place him in a one-year older group. The variance in numbers is also due to inability to secure data for all of the boys first tested, due to sickness, absence and promotion from school, as is true affecting other data throughout this study.

To the elements of the Schneider Test, which consists of six measures secured through cardio-vascular testing and changes involved, have been added certain other physical and physiological measures felt necessary for this thesis. Included in these additions were chronological and physiological age. The Pubic and Axillary Indices as usually checked by presence of hair conditions at those parts were used, along with a Mammary Index discovered by the writer through observation and used for the third test only, in determining physiological age.

Equipment used in conducting the test was a small massage plinth or table, a stop-watch, calibrated in one-fifth seconds; a large size diaphragm stethoscope, and a sphygmomanometer, Baumanometer type, with four-inch width rubber air-pressure collar and vertical mercury millimeter calibration.

All heart rates were apex heart-beat count with the aid of stetho-

scope and stop-watch. The blood-pressure readings were taken on the left arm, systolic readings only being taken, aided by the stethoscope pulsation detection.

The exercise test consisted of alternate forward raising of the flexed leg with the knees to a horizontal position indicated by bringing the knees against the hands held at a hip horizontal position. One foot was in contact with the floor at all times, the count for Test I being ten knee raisings in five seconds, and for the second and third tests twenty knee raisings in ten seconds. It was found upon testing that the knee raisings were as good a measure as an exercise as was the Schneider chair stepping test which is more difficult to supervise.

THE SCHNEIDER TEST AS AN INDEX OF PHYSICAL CONDITION FOR BOYS

In this study as heretofore mentioned the "Schneider Test," so called has been used along with the other data. It is with particular reference to these cardio-vascular tests, developed by Dr. E. C. Schneider of Middletown, Connecticut, as a result of his experience with aviators during the World War, and their desirability for determining physical fitness among boys, that their use has been made in this thesis study.

There is a great need for some measure showing the physical condition of boys. The possibility of the adoption of such tests by physical educators for correlation with their physical examinations has led the writer to make this study in an attempt to determine whether the Schneider Test might fit that need. So much success has been shown and at present is being experienced with this test among the aviators that it is possible it might be adaptable to the needs of other fields where physical fitness is an important factor.

Many types of tests have been used, all showing a partial measure of success, but in no case fully meeting the need. It is possible that a physiological rating might better serve this end than some measure of athletic activity or sport event testing as so often used.

The Schneider Test[1] consists of six cardio-vascular measures in the horizontal and vertical positions and the differences between the scores in these various positions as follows:

1. Normal heart rate lying or horizontal.
2. Normal heart rate standing or vertical.
3. The difference between these two rates.
4. The difference between the lying and standing blood pressure.
5. The heart rate immediately after exercise.
6. The heart rate recovery or return to normal.

[1] Further details referring to this test may be found in a reprint from the *American Physical Education Review* for April, 1922, entitled "Tests of Physical Efficiency" by Burton Opitz, also from the *Journal of the American Medical Association* for May, 1920, pp. 1507-10, an article by Dr. Edward C. Schneider, entitled, "A Cardio-vascular Rating as a Measure of Physical Fatigue and Efficiency."

All of these 6 tests are scored on a basis of from plus 3 points as the maximum to a —3 points as the minimum against tabulated scores as worked out by Dr. Schneider. A perfect score would show 18 points and is secured by totaling the scores made for all 6 tests. No changes in this check-up have been made from the Schneider scoring. With the above considerations in mind a check-up of the boys' scores with the Schneider Test show the following efficiency ratings:

TABLE I[2]

EFFICIENCY ACCORDING TO SCHNEIDER TEST SCORING

	Test I	*Test II*	*Test III*
Efficient	96 boys—34%	74 29%	43 18%
Inefficient	186 boys—66%	181 71%	196 82%

The marked decrease in efficiency between the three tests can largely be accounted for by the fact that there was a difference in the exercise given for Test I than for Tests II and III.

The basis for determining efficiency according to Dr. Schneider is a score of ten points or better.

Table II gives a detailed tabulation of the scores and the number of boys scoring points accordingly for the three tests, without regard to chronological age or physiological age. The median or average score of all the boys for each test is also listed. In Test I 50 per cent of the scores lay between 5 and 11 points scored. Were the efficiency scoring value reduced the percentages of boys showing efficiency would have been as follows: Nine points—42 per cent efficiency; eight points—52 per cent efficient; seven points—62 per cent efficient; and if six points 70 per cent efficient. It is believed that a score of six points as the efficiency scoring value would more truly represent the condition of the group.

Tabulating after similar manner to Table II for efficiency scoring as related to chronological age: It being impossible in this brief digest to include all the tables, I shall outline the outstanding points brought out by this study.

It can be seen from the mean scores that the twelve-, thirteen-, and fifteen-year groups with an average score of seven points ranked the highest. The lower scores of the two age groups at each extreme are due partly to the small number of cases scored to compute a fair mean value.

There does not appear to be any marked difference in the scores for the various age groups; all groups have some high and some low scores. The means show this similarity quite strikingly; so that one can not say that any chronological age group scored better than or is more efficient physically than another.

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[2] Statistical procedures for these data were according to those set up by H. O. Rugg, in his book, *Statistical Methods Applied to Education.*

TABLE II

COMPARISON OF SCHNEIDER TEST EFFICIENCY SCORES

Point Scores	*Test I Cases*	*Test II Cases*	*Test III Cases*
18	..	..	..
17	2	2	..
16	2	2	2
15	8	4	..
14	17	7	4
13	12	16	3
12	15	12	11
11	16	15	4
10	24	16	19
9	23	17	14
8	27	18	13
7	26	19	17
6	24	24	16
5	18	18	23
4	12	21	16
3	18	16	24
2	15	9	12
1	12	12	13
0	3	7	14
— 1	2	8	8
— 2	1	5	3
— 3	2	3	10
— 4	1	1	6
— 5	1	..	3
— 6	..	..	3
— 7	1	..	..
— 8	..	3	..
— 9	..	..	..
—10	..	..	1
Median Score	8.1	7.2	5.3

Considering after a similar manner the tabulated scores for the physiological age groups: In most cases the prepubescent groups show a better mean efficiency score, which leads one to conclude that the youngest boys were in the best physical condition. This is true for all but the pubescent group in Test I, which group shows a mean value of eight; and for the postpubescent group in Test III, where the mean score was among the highest, being seven points.

Comparing the physiological age groups, pubescent, axillary, mammary, as a whole the mammary index group scored the lowest in Test III for the prepubescent and postpubescent mean value. It is hardly fair, however, to say that this can be a final conclusion for this index, as sufficient data have not been gathered in this study, the mammary index being checked for Test III only.

From computations made, considering the mean points scored, for

the six items of the Schneider Test items of efficiency, show Test I as scoring better than Tests II and III in three of the determinations. The mean value of Test III for the heart rate difference is lower by one point than is that of Tests I and II, being zero points as against one point. The heart rate after exercise shows a mean score decrease of one point each respectively for Tests II and III below that of Test I, which averages two points. The blood-pressure difference mean for Tests II and III averages zero, while Test I shows a score of one. The other three determinations means for horizontal and vertical heart rate and their difference show the same result.

These mean scores also show that the heart-rate recovery ranked the highest for the six determinations with a score of two points. Also that the blood-pressure difference ranked the lowest in the mean value of all six items scored.

One can readily see, from the low mean scores for the six items or determinations, that the scoring of the results of tests for boys against a table calibrated for men is not a fair determination of efficiency. While the writer believes that the six items in the test as such are positive factors, upon a physiological basis, against which to determine physical condition, he does not feel that only 34 per cent of the boys are efficient physically as shown through the Schneider scoring for Test I. With this in mind and with the mean values as aforementioned and with the computation for Test I showing that 70 per cent of the boys would be efficient if a score of six points and above were used, it is believed the Schneider Test could be used as a fair basis of determining physical fitness or condition. This figure of six is also arrived at as the minimum figure for scoring efficiency through a total of the means averaged for the six items tested.

The fault found with the Schneider Test for determining efficiency during the adolescent years lies not in the test items, but in the scoring values as follows:

1. It is unfair to check boys against a table calibrated for men.
2. The tabulations for men necessarily make no provision for a difference in physiological age.
3. All extremely high or low heart rates and blood pressures must be scored against the maximum or minimum value regardless of their possible scoring value.
4. The highest points are given for a plus blood pressure when the majority of cases for boys are a minus pressure in the vertical position.
5. The rate of the heart beat obviously cannot be computed immediately after exercise, but must be recorded and computed at one-third, one-fourth, one-half, or one-minute intervals after the exercise, thus not being a true figure.

CONCLUSIONS

Having simplified the method of presentation of the data and facts in this digest and having discarded as useless for including in these pages much computation, mathematical formulae and tabulations, the writer wishes to summarize the outstanding points resulting from the study.

1. The Schneider Test is a fair index for determining physical condition, providing the scoring basis is readjusted for boys.

2. Physiological age as a basis for classifying groups is a better index than chronological age.

3. In so far as this study shows, the axillary index is of doubtful value in determining physiological age.

4. The pubescent index and the writer's originated mammary index more nearly parallel one another and are better measures for determining pubescent age.

5. The exercise test of twenty knee raisings in ten seconds is of greater value and easier accomplished than the Schneider chair standing exercise.

6. Excitation in boys is so marked in a study of this nature that for the truest value the first test should be a practice test, the data not to be used except for comparison.

7. Much more scientific work and mathematical computation need to be conducted before definite conclusions regarding condition can be stated finally.

8. Conditions under which the tests are conducted should be as nearly identical as possible for proper comparison of results.

9. At least one hundred subjects for each physiological age group is best for showing a true relationship.

Selected Bibliography of Graduate Theses, Springfield College, 1929-1934

Compiled by G. B. Affleck, A.M., M.P.E.

THE Master of Education and the Master of Physical Education degrees involve the satisfactory completion of thirty-one semester hours beyond the Springfield Bachelor of Science or Bachelor of Physical Education or their equivalents.

Among these requirements is a thesis which is regarded as the equivalent of a one-year course.

The theses selected for listing below are deemed deserving of inclusion on the basis of their technical contribution to physical and health education.

These are typed and bound and are available for loans, preferably through library exchanges.

THESES FOR MASTER'S DEGREES 1929-1934

1929

Bartolome, C. C.—Physical Measurements of Freshmen Filipino Students in the University of the Philippines.

Grunberg, A. A.—Short Static Contractions as an Aid in Corrective Gymnastics.

Holloway, T. F.—Learning of the Big-Muscle Skills in Soccer.

Karpovich, P. V.—Study of Some Physiological Effects of Golf.

Kindle, W. H.—Special Study of Physical Education in Southern Secondary Schools for Negroes.

Latto, W. T.—Physical Education in the Small College.

Moorhead, W. G.—State Organization and Administration of Health and Physical Education in High Schools.

Pennock, E. W.—Study of Physical Condition in Relation to Heart Rate and Blood Pressure During Adolescence.

Quimby, R. C.—Weight and Physical Measurement, Correlations and Comparisons.

West, W. D.—Study of Physical Condition of Adolescent Boys in Relation to Heart Rate, Blood Pressure and Pubescence.

1930

Booth, T. W.—Physical Growth and Pubescence.

Cureton, T. K., Jr.—Objective Tests of Swimming.

Gemme, A. L.—Study of Corrective Work for College and Secondary School Groups.

Gramley, J. C.—Study of Foot Impressions of Junior High School Boys.

Greene, M. M.—Energy Cost of Track Running and Swimming.

Hughes, R. P.—Study in Short Static Strength of Muscles in Relation to Posture of School Boys.

Johnson, H. C.—Physical Measurements of Growth and Nutrition.

LaBree, L. W.—Study of Short Static Contractions as an Aid in the Department of Corrective and Remedial Gymnastics in Universities and Colleges.

Martie, J. M.—Physical Development in Relation to Gymnastic Exercises and Sports.
Tousley, C. V.—Seasonal Increments of Growth in Weight According to Age of Grade School Boys.
Vejchoda-Ambros, M.—Curriculum Study; A Study of 108 Colleges and Universities Preparing Teachers in Physical Education in the United States.
Vibberts, C. D.—Methods of Having Health and Physical Education Accepted in the Educational Curriculum with Definite Credit Being Given Toward Graduation.

1931

Burr, J. H.—Survey of Physical Education in Negro Colleges and Universities.
Graziano, G.—Physical Education Under the Fascist Regime.
Guyer, R. J.—Weight and Physical Measurement Correlations.
Hanson, R. W.—Physical Education, Hygiene and Athletic Administration in Public High Schools of Illinois.
Liu, S.—Needs of China in Physical Education.
Ludwig, L. T.—Physique and Physical Fitness.
McCarraher, J. D.—Survey of Physical Education and Hygiene in Country Day Schools for Boys in the United States.
Mooney, B. F.—Effect of Wrestling on Muscular Strengths.
Seitzer, P. S.—Efficiency and Accuracy in Postural Strength Tests.

1932

Andrews, G. F.—History of the Playground Movement and Organization and Administration of Playgrounds.
Bakeman, A. R.—Study of the Springfield Alumni.
Davis, C. A.—Experiments in Measuring Ability and Progress in Basketball Skills.
Dimperio, P. P.—Juvenile Delinquency in Relation to Municipal Recreation.
Ellis, A. W.—Study of Football Skills in Relation to Accidents.
Fasulo, T.—Corrective Gymnastics in the United States.
Griffiths, M. G.—Bacteriological Analysis of Swimming Pool Waters.
Hawkins, C. C.—Effects of Training in Swimming upon the Morphological Composition of the Blood.
Huff, F. H.—Physical Education, Hygiene and Athletic Administration in Public High Schools of West Virginia.
Joseph, P. M.—Effect of Modifications in Respiration on Speed of Recovery from Fatigue.
Lux, L. H.—Study of Breath Holding.
Mattia, E. A.—Physical Education and the Boy; A Program in the Y.M.C.A.
Oosting, R.—Study of Graduate Opinions on Questions Relating to Athletics and Physical Education.
Stark, L. W.—Survey of Physical Education and Athletic Administration in Catholic Colleges and Universities.

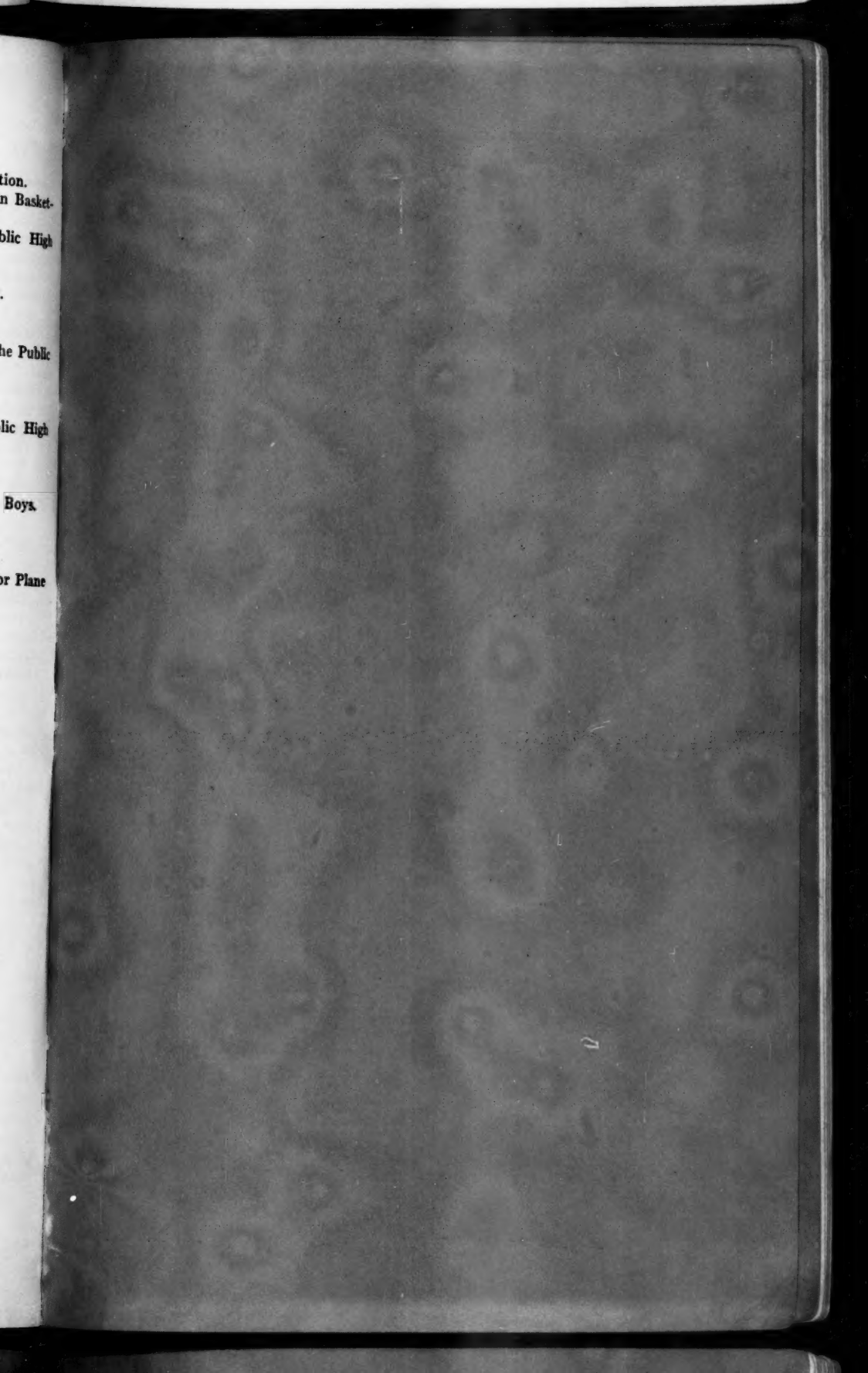
1933

Allen, H. R.—Mechanics and Kinesiology of the Frog Kick as Used in the Breast Stroke.
Bitgood, P. E.—Seasonal Increments of Growth in Height According to Age of Elementary School Boys.
Danielson, A. J.—Health and Physical Education for Schools of India.
Davies, W. T.—Motivation in Intramural Basketball Skills.
Dodds, A.—Status of Girls' Athletics in the High Schools of Pennsylvania.
Gipson, C. F.—Effect of Exercise on Antero-Posterior Posture of College Freshmen.
Gunby, W. E.—Physical Tests of Antero-Posterior Spinal Measurements.
Gunkler, O. H.—Body Mechanics and Physical Fitness as Related to Intelligence, Scholarship, and Physical Education Grades.

Henre, M. R.—Studies of Maintenance of Equilibrium in Standing Position.
Kelley, C. C.—Experiments in Measuring Accuracy and Reaction Time in Basketball Officiating.
Larson, L. A.—Survey of Physical and Health Education in the Public High Schools of Minnesota.
Parry, K. R.—Learning Process in Tumbling for the Elementary Grades.
Weitzdorfer, R.—Recreation and Aesthetic Culture of Youth in Germany.
Wilson, C. T.—Coordination Tests in Swimming.

1934

Clark, H. R.—Supervision of Student Teaching in Physical Education in the Public Schools of Springfield, Mass.
Diamantides, G. D.—Grecian Physical Education, 1834–1934.
Fraser, D. C.—Motor Ability Tests in Baseball.
Johnson, P. E.—Survey of Health and Physical Education in the Public High Schools of Massachusetts.
Nagle, J. L.—A.B.C.D.'s of Tumbling.
Ratiani, N. O.—Underweights.
Ritchie, G. D.—Physical Ability Tests for Junior and Senior High School Boys.
Sargeant, B. P., Jr.—Effect of Wrestling on Systolic Blood Pressure.
Weckwerth, C. F.—Classification Test for Beginners in Dancing.
Welser, L.—Practical Electro-Mechanical Race Timer.
Wickens, J. S.—Center of Gravity of Human Body in the Antero-Posterior Plane and Its Relation to Posture.



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